北海道帝國大學農學部紀要

第三十八巻

JOURNAL

OF THE

FACULTY OF AGRICULTURE,

HOKKAIDO IMPERIAL UNIVERSITY

Vol. XXXVIII

北海道帝國大學刊行

昭和十年—昭和十二年

SAPPORO, JAPAN

PUBLISHED BY THE UNIVERSITY

1935–1937

42852
15 FEB 1939

CONTENTS OF VOLUME XXXVIII

1. **Chemical and Physico-Chemical Studies on the Starches**
Yukihiko Nakamura 1

2. **Der Einfluss der Eierbehandlung mit Zentrifugierung auf die Vererbung bei dem Seidenspinner**
I. Über experimentelle Auslösung der polyploiden Mutation
Eisaku Kawaguchi 111

3. **Artificial Insemination of *Bombyx mori***
Seinosuke Ômura 135

4. **Studies on the Reproductive System of the Male of *Bombyx mori***
I. Structure of the Testis and the Intratesticular Behaviour of the Spermatozoa
Seinosuke Ômura 151

5. **Erysiphaceae of Japan**
Yasu Homma 183

CHEMICAL AND PHYSICO-CHEMICAL STUDIES ON THE STARCHES

By

Yukihiko NAKAMURA

Contents

		Page
Introduction		2
Experiments and Discussions		5
Materials		5
Chapter I.	Studies on the Original Starches	5
§ 1.	Water and ash content of the starches	5
§ 2.	Phosphorus content of the starches	7
§ 3.	Nitrogen content of the starches	10
§ 4.	Acetylation of the starches	12
§ 5.	Benzoylation of the starches	20
§ 6.	Nitration of the starches	24
§ 7.	Mechanism of the hydrolysis of the starches by the action of the diastase	28
§ 8.	Viscosity of the solution of the starches	36
§ 9.	Electrical conductivity of the solution of the starches.	38
§ 10.	Influence of salts added to the solutions of the starches upon the viscosity of the solutions	40
§ 11.	Gold value of the starches	44
§ 12.	Heat of combustion of the starches	45
§ 13.	Adsorption of iodine by the starch granules	46
Chapter II.	Electrodialysis of the Starches	51
§ 1.	Method	52
§ 2.	Water, phosphorus and nitrogen content of the electrodialysed starches	54
§ 3.	Acetylation of the electrodialysed starches	57

[Jour. Facul. Agr. Hokkaido Imp. Univ. Sapporo, Vol. XXXVIII, Pt. 1, Dec. 1935]

§ 4. Electrical conductivity of the solution of the electro-dialysed starches 59
§ 5. Viscosity of the solution of the electrodialysed starches. 61
§ 6. Gold value of the electrodialysed starches 62
§ 7. Adsorption of iodine by the electrodialysed starch starches by the action of the diastase 63
§ 8. Mechanism of the hydrolysis of the electrodialysed granules 66
Chapter III. Oxidation of the Starches 71
§ 1. Method 71
§ 2. Acetylation of the oxidised starches 73
§ 3. Viscosity of the solution of the oxidised starches 74
§ 4. Adsorption of iodine by the oxidised starch granules . 77
Chapter IV. Phosphoration of the Starches 84
§ 1. Ash, phosphorus and calcium content of the phosphorated starches 85
§ 2. Viscosity of the solution of the phosphorated starches. 87
§ 3. Electrometric titration of the phosphorated starches . 93
Conclusions 96
Literature 102

Introduction

The manufacture of starch from cereal grains has been practiced from very early times. In 184 B.C., Marcus Parcuis Cato described the fact. According to Pliny the Elder, the method for the extraction of starch from cereal grains was said to have been found by the inhabitants of the Island of Cios. From that time to the latter half of the 18th century, the source material practically used for the purpose of manufacturing starch was limited to wheat.

In the middle ages, the manufacture of wheat starch resulted in an important industry in Holland and the Dutch were famous for the quality of their starch. At that time, starch was used mainly in laundries. In the 16th century, it became the custom in France to powder the hair with starch and the custom continued till the end of the 18th century consuming an immense quantity of starch. Leonald da Vinci had intended to stiffen the wings of his flying machine with starch.

In the 18th century, the search for materials for starch manufacture cheaper than the wheat was carried out. In 1732, Sieur de Guife proposed to the French Government to use potatoes. In 1765, the manufacture of potato starch was carried on with the encouragement of Frederick the Great in Germany. In 1772, Duhamel de Monceau had made clear that the arrowroot, potato and arum could be used instead of the cereal grains. At that time, starch was used for the preparation of cosmetic powder, in colour printing, in tablets, in some mixture of soap, etc. In 1796, Murray proposed to use the horsechestnut, and in 1799, Gibbs proposed to use the root of Arum maculatum as the materials for starch manufacture.

In the 19th century, starch was used in the textile, colour printing and paper industries. It was discovered that starch could change easily into glucose and dextrin, the demand for it became very large. The starch industry showed an enormous expansion. From the beginning of the 19th century potatoes were largely used for starch manufacture chiefly in Germany, then followed maize which was the principal raw material in the United States. From the middle of the 19th century rice also has been employed on a large scale.

In this country, the arrowroot starch has been used from early times. Also bracken powder and other sources were employed. About 1835 (in the 5th year of Tempo), the manufacture of sweet potato starch began in the province of Shimoosa. About 1870 (in the beginning of Meiji), the potato starch was produced accompanying the import of the potato. The sale of starch as a foodstuff began in about 1870 (in the 3rd year of Meiji). At the present time, potato starch is produced mainly from Hokkaido and sweet potato starch is produced mainly from the province of Chiba.

As starch was used very widely for many purposes, there was need to know its characteristics and its general properties. Thus chemical and physico-chemical studies were carried out from very old time and a great many authors had reported the colloid chemical, physico-chemical and chemical properties of the starch up to the recent days.

According to the idea of AME PICTET(111_1), starch is made up by the binding of groups which will produce the d-glucose when the starch is treated by thermal depolymerisation; the formula of the starch is expressed by $C_6H_{10}O_5$ or $(C_6H_{10}O_5)_n$, the half of the binding of the $C_6H_{10}O_5$-group is at least in the α-linkage forming whole

molecule with the β-linkage. Similar to KARRER's opinion is the opinion of PRINGSHEIM, IRVINE, HESS, KUHN and BERGMANN, who considered that the $C_6H_{10}O_5$-group is combined to some extent by polymerisation, but the starch molecule is made up by the association of such relatively simple polymerisation products. The formation of hexahexosan results from the polymerisation of $C_6H_{10}O_5$-molecule and the formation of starch results from the association of hexahexosans, so that the starch is not considered as a molecule of certain magnitude, but as a polyhexosan. Considering from the results of the methylation of starch and the physiological phenomena, J. IRVINE(111_2) concluded that starch is not a homogeneous chemical individual, but a combined product of molecular units which vary their content of inorganic acid residue. The simplest possible formula has considered the molecular unit as an anhydrohexaglucose. Standing on the results of an enzymic hydrolysis of the starch, A. R. LING(111_3) discussed the structure of the starch molecule. He concluded that starch had contained two basal units i.e. α-hexaamylose and $\alpha\beta$-hexaamylose and that these were polymerised to a particular degree according to the kind of starch. α-amylose and amylopectin were produced by the mentioned polymerisation; a third substance, amylohemicellulose, was also produced in cereal starch by such polymerisation. H. PRINGSHEIM(111_4) observed that in the course of the bacterial degradation of starch, dihexosan was produced from the amylose and the trihexosan from the amylopectin. Though these hexosans were not considered as structural units of starch, it was proper in his opinion to conclude that the starch, lichenin, cellulose, inulin and salepmannan were complex hexose anhydrides. MAX SAMEC(111_5) stated regarding the relations between the colloid chemical properties and the chemical structure of starch, that the P_2O_5-content of the amylopectin was 0.185% and that of the amylose was 0.007% ; the amylopectin was seen as the starch phosphoric acid ester. Studying the X-ray spectrography of starch, J. R. KATZ(111_6) stated that starch produced a crystalline X-ray spectrum, that the spectra of the starches showed different figure according to their kinds and that those of the swollen starch were all equal, that the spectra of the extremely dried starch and that of the gelatinized starch were different, that the latter had combined with the water, and that the elementary cell of the starch should be very small. KARRER(42) had considered that the elementary molecule of starch should be maltoseanhydride.

The author (62) has reported the results of the differences of chemical and physico-chemical properties of the starches of the brewing barleys according to their species. By the further studies and the comparison of the results of many starches, the author desired to make clear the different properties and the constitution of the starches and for that purpose has carried out the following investigations.

In the whole course of the investigations, Prof. TETSUTARO TADOKORO, Nogakuhakushi, Rigakuhakushi has given the author constant leadings and kind advices for which he is deeply grateful. He wishes to express his hearty thanks to him.

Experiments and Discussions

MATERIALS

The materials used in the present investigations comprise 14 samples of starch from 11 different plant species viz., the potato, dog-tooth violet, wheat, barley, common rice, common Italian millet, common sorghum, corn, cassava, buckwheat and arrowroot. The potato, dog-tooth violet and wheat starches were manufactured by KOJIMA and Co. Tokyo; the common rice, common Italian millet and common sorghum starches were prepared in the Laboratory of Professor TADOKORO in the Department of Agricultural Chemistry of the Faculty of Agriculture, Hokkaido Imperial University. The corn starch was purified by the author by the extraction with 0.2% natrium hydroxide solution of the commercial corn starch manufactured by T. KINGSFORD and Son Co. U.S.A. The potato, cassava, wheat, buckwheat, corn and arrowroot starches were prepared by Professor ITO in the Gifu Koto Norin Gakko.

Chapter I

Studies on the Original Starches

§ 1. Water and ash content of the starches

According to the usual method the water and the ash content of the 14 starches were determined as the following table shows.

TABLE 1.

Water and ash content of the starches.

Starch	Water	Ash (Water free)
Potato (Kojima)	17.30	0.264
Dog-tooth violet	12.88	0.112
Wheat (Kojima)	12.85	0.449
Sorghum	10.16	0.118
Rice	12.48	0.144
Italian millet	7.43	0.182
Barley	11.36	0.075
Corn (Kingsford)	18.47	0.076
Potato (Ito)	16.54	0.170
Cassava	10.51	0.075
Wheat (Ito)	12.44	0.063
Buckwheat	13.20	0.088
Corn (Ito)	11.40	0.046
Arrowroot	10.37	0.068

The ash content of the starches was counted between 0.5% to 0.05% of their dry matter. It seemed to be usual for the ash content of the starches to range 0.2–0.05%. By the comparison of the starches of the cereal plants and the starches of the tubers, it was observed that the ash content of the starches of the latter was higher than that of the starches of the former. The ash content was seen to differ markedly according to the difference of the method of manufacturing as may be seen from the fact that the ash contents of the potato starches were 0.264% and 0.170%, of the wheat starches 0.449% and 0.063%, of the corn starches 0.076% and 0.046% respectively. The same relation was observed in the phosphorus content of the starches as described later.

§ 2. Phosphorus content of the starches

Because of the fact that phosphorus is one component of the starch molecule, its content in starch and its chemical form in the starch molecule have been studied and reported by many authors, amongst whom are FERNBACH (29), FORD (30), MALFITANO (55), FOUARD (32), FRANCIS (34), SAMEC (82), SAMEC and HOEFFT (90), THOMAS (107), SAMEC and JENCIC (91), NORTHRUP and NELSON (64), KERB (45), TRYLLER (110), SAMEC and MAYER (92), EULER and MYRBÄCK (28), TIEBACKX (108), SAMEC and SSAJEVIC (95), MALFITANO and CATOIRE (56), and ROSENTHALER (80). The results of so many authors may be summarized as follows, that is, there is phosphorus in starch, it was said either to be combined with the organic compound of starch forming amylophosphoric acid or to be uncombined but simply adsorbed to the starch molecule, the viscosity of the starch solution is changed proportionately with the phosphorus content of the starch, the saponification of starch is caused by amylopectin which is the ester of the phosphorus, the phosphorus content of starch ranges 0.032–0.169%.

The author determined the phosphorus content of the starches of his investigation as follows. One g of the starch was taken into a Kjeldahl flask to which was added 10 c.c. of the mixture of concentrated sulphuric acid and concentrated nitric acid according to NEUMANN's procedure. The mixture was heated for 1 hour whereupon 2 c.c. of concentrated nitric acid were added and the whole was heated for one hour more. The main part of the acid of the solution was neutralized by the addition of 40% natrium hydroxide solution. With the resulting slightly acidic solution, colorimetric determination of the phosphorus content was carried out according to BELL-DOISY's method modified by BRIGGS (20). The slightly acidic solution was taken into a 100 c.c. measuring flask, to the solution was added water to make the volume up to about 80 c.c. then to the solution were added 5 c.c. of sulphuric acid—ammonium molybdate solution and 1 c.c. of newly prepared 20% natrium sulphite solution and 1 c.c. of 0.5% hydrochinone solution. The mixture was made up to 100 c.c. by the addition of water. After 30 minutes, the colour was compared by means of a Dubosque colorimeter with the standard solution prepared in the same way using a standard kalium phosphate solution. The results are shown in the following table.

TABLE 2.

Phosphorus content of the starches.

Starch	P (Water free)	P_2O_5 (Water free)
Potato (Kojima)	0.053	0.122
Dog-tooth violet	0.025	0.057
Wheat (Kojima)	0.059	0.134
Sorghum	0.020	0.045
Rice	0.022	0.051
Italian millet	0.021	0.049
Barley	0.025	0.058
Corn (Kingsford)	0.021	0.049
Potato (Ito)	0.047	0.108
Cassava	0.021	0.049
Wheat (Ito)	0.015	0.035
Buckwheat	0.017	0.038
Corn (Ito)	0.019	0.043
Arrowroot	0.021	0.049

The table shows that the phosphorus content of the starches was 0.134–0.035% and that the content was always great in the potato starches. Generally speaking, the phosphorus content of the starches ranged 0.058–0.035%. The results coincide very well with those reported by many other investigators. The phosphorus content of the starches differed very markedly according to the method of preparation of the starches. This may be seen in the potato starches containing respectively 0.122% and 0.108%, and also in the wheat starches showing 0.134% and 0.035%. The phosphorus content of the corn starches was 0.049% and 0.043% which resembled each other. The reason for this fact was considered to be that the purification of the starches were carried out by the use of natrium hydroxide solution in both cases and that the same treatment affected the two substances similarly. Treatment with natrium hydroxide solution seemed to diminish the phosphorus content of the starch. It seems that natrium hydroxide has some effect upon the separation of the phosphorus of the starches as in the case of the separation of the phosphorus of protein.

The difference between the ash content of the starches and their P_2O_5 content; the ratio of that difference to the ash content and the ratio of the P_2O_5 content to the ash content were calculated as follows.

TABLE 3.

Difference between the ash content and the P_2O_5-content; the ratio of the P_2O_5 to the ash content and of the difference to the ash content in terms of percentage.

Starch	Ash $-P_2O_5$	$\frac{\text{Ash}-P_2O_5}{\text{Ash}}\times 100$	$\frac{P_2O_5}{\text{Ash}}\times 100$
Potato (Kojima)	0.142	53.78	46.22
Dog-tooth violet	0·055	49.10	50.90
Wheat (Kojima)	0.315	70.15	29.85
Sorghum	0.069	58.47	41.53
Rice	0.093	64.58	35.42
Italian millet	0.137	75.27	24.73
Barley	0.017	22.68	77.32
Corn (Kingsford)	0.028	36.84	63.16
Potato (Ito)	0.062	36.47	63.53
Cassava	0.026	34.67	65.33
Wheat (Ito)	0.028	44.44	55.56
Buckwheat	0.050	56.82	43.18
Corn (Ito)	0.003	6.52	93.48
Arrowroot	0.021	30.89	69.11

Comparing the ash content and the P_2O_5 content of the starches and the differences between the content of ash and the P_2O_5 content, the author was able to divide the starches into two groups, one of which had increasing P_2O_5 content with increasing ash content and the other had decreasing P_2O_5 content with increasing ash content. The percentage of P_2O_5 in the ash of the starches from the tubers was greater than those of the starches from the cereal plants. The method of preparation of the starches had no influence upon the percentage, since almost equal percentages were found notwithstanding the difference in methods of preparation. Accordingly in the course of the preparation of the starch, the constituents of the ash

of the starches other than P_2O_5 were also lost in the same proportion as in the case of the P_2O_5. It was generally found that the ash constituents of the starch had to play an important role in the construction of the starch and that the proportion of the ash constituents other than P_2O_5 to the P_2O_5 was almost constant to each starch.

§ 3. Nitrogen content of the starches

J. M. NORTHRUP and J. M. NELSON (64) reported that starch contained less than 0.1% of nitrogen in the granule. L. MOESER (58) observed that the commercial starches contain 0.03–0.7% of nitrogen and that for the purpose of removing it the starch has to be treated with alcoholic potassium hydroxide or natrium hydroxide solution. J. C. IRVINE with J. MACDONALD (40), however, reported that nitrogen is absent from the starch. O. S. RASK and C. L. ALSBERG (75) reported that wheat starch contains 0.039% of nitrogen. Recently, SAMEC and BENIGER (87) confirmed the existence of nitrogen in the starches of the wheat and the potato amounting to 0.076–0.0049% and they also reported that nitrogen was present in starch as the form of phytovitellin which combined with the polysaccharide in the phosphorus.

The author digested 1 g each of the starches with 1 g of copper sulphate, 1 g of potassium sulphate and 15 c.c. of concentrated sulphuric acid, then the nitrogen was determined by the micro Kjeldahl method as follows.

TABLE 4.

Nitrogen content of the starches.

Starch	N (Water free) %	Starch	N (Water free) %
Potato (Kojima)	0.0198	Corn (Kingsford)	0.0227
Dog-tooth violet	0.0481	Potato (Ito)	0.0070
Wheat (Kojima)	0.0176	Cassava	0.0041
Sorghum	0.0254	Wheat (Ito)	0.0111
Rice	0.0184	Buckwheat	0.0467
Italian millet	0.0332	Corn (Ito)	0.0236
Barley	0.0169	*Arrowroot*	0.0048

The table shows that the nitrogen content of the starches runs 0.004–0.05%, mainly 0.02% or so.

To compare the content of the phosphorus and the content of the nitrogen, the author calculated their molecular number. The ratio of the two components was calculated and tabulated as follows.

TABLE 5.

Molecular numbers of the phosphorus and the nitrogen contained in 100 g of the starches and their ratio to each other.

Starch	Phosphorus	Nitrogen	P : N
Potato (Kojima)	0.001708	0.001414	1 : 0.828
Dog-tooth violet	0.000806	0.003434	1 : 4.262
Wheat (Kojima)	0.001902	0.001257	1 : 0.661
Sorghum	0.000677	0.001813	1 : 2.679
Rice	0.000709	0.001314	1 : 1.852
Italian millet	0.000642	0.002370	1 : 3.677
Barley	0.000806	0.001207	1 : 1.497
Corn (Kingsford)	0.000677	0.001619	1 : 2.394
Potato (Ito)	0.001515	0.000500	1 : 0.330
Cassava	0.000677	0.000293	1 : 0.433
Wheat (Ito)	0.000484	0.000793	1 : 1.643
Buckwheat	0.000548	0.003334	1 : 6.085
Corn (Ito)	0.000613	0.001685	1 : 2.751
Arrowroot	0.000677	0.000343	1 : 0.506

It may be seen from the table that the ratio between the phosphorus and the nitrogen was 0.3–6.0. This ratio in the case of the tuber starches, with the exception of the dog-tooth violet starch, was 0.3–0.8 while that of the cereal plant starches was 0.6–6.0. The former was markedly small compared to the latter. Thus, it is possible to say that the starches could be divided into two groups, that is those of the tubers and those of the cereal plants.

§ 4. Acetylation of the starches

The acetylation of the starch was carried out by SCHUETZENBERGER (97) for the first time in the year 1865. From that time, the acetylation of starch and soluble starch has been carried out by many authors as follows: SCHUETZENBERGER and NAUDIN (99), SCHUETZENBERGER (98), MICHAEL (57), SKRAUP (102), PREGL (69), CROSS, BEVAN and TRAQUAIR (25), SKRAUP, GEINSPERGER, KNAFFL-LENZ, MENTER and SIRK (103), LAW (49), TRAQUAIR (109), PRINGSHEIM and LANGHAUS (71), PRINGSHEIM and EISSLER (70), BÖESEKEN, BERG and KERSTJENS (17), KARRER (44), BERGMANN and BECK (8), KARRER and SMIRNOFF (43), PRINGSHEIM and LASSMAN (72), ZECHMEISTER (114), ESCALES and LEVY (27), PRINGSHEIM and WOLFSOHN (74), SJÖBERG (101), BERGMANN and LUDEWIG (9), PEISER (67), BERGMANN, KNEHE and LIPPMANN (10), HAWORTH, HIRST and WEBB (36), FRIESE and SMITH (35), BRIGLE and SCHINLE (21). Summarizing the results of these authors, it may be reported that the reagents used were acetic acid, glacial acetic acid, acetic acid anhydride and acetyl bromide, the catalyser was either used or not used, when the catalyser was used it was either sulphuric acid, hydrochloric acid, hydrobromic acid, zinc chloride or pyridine, the temperature of the reaction was either the room temperature, lower than 80°C., 100–105°C., 140°C. or 150°C., and the time of the reaction was more than one hour to many days. The acetyl compounds resulting from the above various treatments were very different respectively. The content of the acetyl group of the compound was 2.8–17.4%, 45–48% or the reaction products were starch triacetate, starch hexaacetate and starch nonaacetate. In the course of the reaction, there were produced soluble starch, dextrine or substances which possessed the reducing power by hydrolysis or saponification. TRAQUAIR gave the name feculose to the acetic ester of starch. KARRER considered that the acetylation of the starch did not change the degree of polymerisation. ESCALES and LEVY reported that the starch did not produce any destructive depolymerisation by the process of the acetylation.

(a) *Acetylation of the starch at high temperature*

In an earlier paper, the author has already reported the results of the acetylation of the starch of barley and rice by means of acetic

acid anhydride and zinc chloride. The author treated the starches of the present investigation by the same method as follows. To ten g of the starch were added 0.5 g of zinc chloride and 100 g of acetic acid anhydride (Merck) and the mixture was heated on a sand bath with a reflux condenser for 3 hours. At the end of that time, the clear solution obtained was poured into cold water in a fine stream. The precipitate thus obtained was washed carefully with water until no acid reaction was observed in the washings. The precipitate was then dried in a water oven at 100°C. for 5 hours and was stored in a desiccator of sulphuric acid. The content of the acetyl group of the product was estimated by WENZEL's method, the rotatory power of the product was measured by means of a GOELTZ-LIPPICH polariscope, the melting point of the product was estimated using THIEL's apparatus making the necessary corrections and the refractive index of the product was measured by means of a GOELTZ refractometer. The rotatory power and the refractive index were estimated with the solution of 0.2 g of the product dissolved in 15 c.c. of pyridine 5 hours after the time of solution.

TABLE 6.

Acetyl content of the acetyl starches. Two tenths g of the sample was used. One c.c. of sulphuric acid corresponded to 0.01293 g of CH_3CO.

Starch		H_2SO_4 (c.c.)	Acetyl group (g)	Acetyl content (%)
Potato (Kojima)	(1) (2)	6.95 6.95	0.089863	44.93
Dog-tooth violet	(1) (2)	7.0 7.0	0.09051	45.26
Wheat (Kojima)	(1) (2)	7.05 7.05	0.09156	45.58
Sorghum	(1) (2)	7.15 7.15	0.0924495	46.22
Rice	(1) (2)	6.9 6.9	0.089217	44.61
Italian millet	(1) (2)	7.2 7.15	0.09277	46.38
Barley	(1) (2)	7.3 7.3	0.094389	47.19
Corn (Kingsford)	(1) (2)	7.0 7.0	0.09051	45.26

TABLE 7.

Melting point, rotatory power and refractive index of the acetyl starches.

Starch	M.P.	α	$[\alpha]$	n
Potato (Kojima)	151.0	3.56	133.50	1.536
Dog-tooth violet	136.5	3.50	131.25	1.542
Wheat (Kojima)	150.0	3.54	132.75	1.552
Sorghum	150.0	3.77	141.38	1.548
Rice	149.0	3.62	135.75	1.550
Italian millet	146.0	3.60	135.00	1.538
Barley	148.0	3.54	132.75	1.556
Corn (Kingsford)	157.0	3.80	142.50	1.543

The acetyl starches were easily soluble in pyridin, aceton and chloroform, soluble in benzol and soluble with difficulty in carbon tetrachloride. The elementary analysis of the compounds was carried out by PREGL's micro-method with the following results.

TABLE 8.

Elementary analysis of the acetyl starches.

Starch	Sample (mg)	H_2O (mg)	CO_2 (mg)	H (%)	C (%)
Potato (Kojima)	3.830	2.290	7.230	6.688	51.47
	3.740	2.160	6.990	6.462	50.97
				6.58	51.22
Dog-tooth violet	5.250	2.800	10.250	5.967	53.23
	4.210	2.390	8.200	6.351	53.11
				6.16	53.17
Wheat (Kojima)	4.110	2.540	7.880	6.913	52.29
	4.300	2.540	8.270	6.607	52.43
				6.76	52.36
Sorghum	5.920	3.470	10.430	6.557	48.03
	3.320	1.825	5.980	6.151	48.39
				6.35	[illegible]

TABLE 8. (*Continued*)

Starch	Sample (mg)	H_2O (mg)	CO_2 (mg)	H (%)	C (%)
Rice	3.890	2.150	7.890	6.183	55.33
	4.550	2.460	9.300	6.047	55.75
				6.12	55.54
Italian millet	3.840	2.150	7.750	6.236	53.76
	5.085	2.830	10.050	6.226	53.89
				6.24	53.83
Barley	4.285	2.380	8.015	6.215	51.01
	5.010	2.990	9.260	6.677	50.41
				6.45	50.71
Corn (Kingsford)	3.520	1.910	6.620	6.070	51.30
	4.640	2.590	8.730	6.244	51.31
				6.16	51.31

The results have been summarised in the following table.

TABLE 9.

Elementary composition of the acetyl starches.

Starch	C	H	O
Potato (Kojima)	51.22	6.58	42.20
Dog-tooth violet	53.17	6.16	40.77
Wheat (Kojima)	52.36	6.76	40.88
Sorghum	48.21	6.35	45.44
Rice	55.54	6.12	38.34
Italian millet	53.83	6.24	39.93
Barley	50.71	6.45	42.84
Corn (Kingsford)	51.31	6.16	42.53

From the above table, it was observed that the higher the content of the acetyl groups of the acetyl starch, the lower were the melting point and the rotatory power and the higher was the refractive index of the compound, and vice versa.

With the assumption that the hydroxyl group in the glucose residue of the molecule of the starch was replaced by the acetyl group

when the acetylation of the starch was carried out, the theoretical content of the acetyl groups of the acetyl starch was calculated as shown in the next table.

TABLE 10.

Theoretical content of the acetyl groups of acetyl starch.

Glucose residue	CH_3CO group	Ratio	Content %
1	1	1	19.37
1	2	2	32.58
1	3	3	42.16
6	19	3.16	43.40
5	16	3.20	43.74
4	13	3.25	44.16
3	10	3.33	44.79
5	17	3.40	45.30
2	7	3.50	46.03
5	18	3.60	46.73
3	11	3.66	47.21
4	15	3.75	47.78
5	19	3.80	48.10
6	23	3.83	48.35
1	4	4	49.43

The content of the acetyl group in the author's acetyl starches was 44.93–47.19%. If these numbers were compared with the calculated numbers shown in the above table, it may be seen that the ratio of the author's acetyl starches lie between 3.33 to 3.66. The mean of the values approximated to 3.50. It may be seen, therefore, that the author's acetyl starches are compounds which were built up with 2 glucose residues and 7 acetyl groups, that is, mixtures of equal quantity of triacetyl glucose and tetraacetyl glucose. In other words it may be said that the compounds are aggregates of heptaacetyl maltose.

(b) *Acetylation of starch in room temperature*

The above mentioned acetylation was carried out at the boiling point of the acid used and it may be that more or less changes of the

starches occur such as hydrolysis or depolymerisation. The acetylation of the starches was therefore repeated according to the method reported by H. FRIESE and F. A. SMITH (35). Three g of the starches were soaked in 8 c.c. of 80% pyridin for one night, to the mixture were added 20 c.c. of pyridin and 20 c.c. of acetic acid anhydride. The mixture was stood at room temperature with an occasional shaking. The viscous liquid thus obtained was poured into a large quantity of cold water and the product was precipitated from the solution. The precipitate was carefully washed with water and dried in a desiccator of diminished pressure of sulphuric acid as described above.

The content of the acetyl group of the product was estimated as follows. A given quantity of the sample was taken in a given quantity of natrium hydroxide solution, the mixture was heated in a boiling water bath for 30 minutes under a reflux condenser. At the end of the time and after the saponification of the substance was completed, the remaining natrium hydroxide was titrated by sulphuric acid using phenolphthalein as an indicator. From the results of the titration, the quantities of the acetic acid liberated were determined. The elementary analysis of the compound was carried out by means of the micro-method as described above. The results of the analysis have been enumerated as in the following table.

TABLE 11.

Acetyl content of the acetyl starches. One tenth g of the sample was used. One c.c. of the sulphuric acid corresponded to 0.01291 g of CH_3CO.

Starch		H_2SO_4 (c.c.)	Acetyl group (g)	Its content (%)
Sorghum	(1)	2.6	0.033566	33.57
	(2)	2.6		
Rice	(1)	3.2	0.043571	43.57
	(2)	3.35		
Italian millet	(1)	3.15	0.040344	40.34
	(2)	3.10		
Barley	(1)	1.75	0.022269	22.27
	(2)	1.70		
Corn (Kingsford)	(1)	3.5	0.045185	45.19
	(2)	3.5		

TABLE 11. (*Continued*)

Starch		H_2SO_4 (c.c.)	Acetyl group (g)	Its content (%)
Cassava	(1) (2)	3.4 3.4	0.043894	43.89
Wheat (Ito)	(1) (2)	3.1 3.1	0.040021	40.02
Buckwheat	(1) (2)	3.2 3.2	0.041312	41.32
Corn (Ito)	(1) (2)	3.5 3 5	0.045185	45.19
Arrowroot	(1) (2)	3.3 3.3	0.042603	42.60

TABLE 12.

Elementary analysis of the acetyl starches.

Starch	Sample (mg)	H_2O (mg)	CO_2 (mg)	H (%)	C (%)
Sorghum	3.595 3.615	2.075 2.200	6.370 6.340	6.292 6.808 6.65	47.08 47.82 47.84
Rice	2.905 3.260	1.785 1.990	5.250 5.925	6.874 6.829 6.85	49.29 49.57 49.43
Italian millet	3.160 4.035	1.860 2.340	5.530 7.030	6.585 6.488 6.54	47.72 47.52 47.62
Barley	3.890 5.010	2.475 3.280	6.400 8.195	7.119 7.324 7.22	44.86 44.62 44.75
Corn (Kingsford)	3.755 4.395	2.260 2.640	6.700 7.780	6.733 6.719 6.73	48.66 48.27 48.47
Cassava	6.105 4.870	3.445 2.800	10.890 8.565	6.313 6.433 6.37	47.56 47.97 47.77
Wheat (Ito)	3.690 4.450	2.085 2.430	6.370 7.710	6.292 6.108 6.20	47.08 47.25 47.17
Buckwheat	4.815 4.440	2.635 2.420	8.400 7.775	6.124 6.096 6.11	47.58 47.75 47.66

TABLE 12. (*Continued*)

Starch	Sample (mg)	H_2O (mg)	CO_2 (mg)	H (%)	C (%)
Corn (Ito)	3.765	2.275	6.670	6.759	48.31
				6.76	48.31
Arrowroot	5.820	3.145	10.250	6.045	48.05
	6.030	3.185	10.560	5.909	47.76
				5.98	47.91

The results were summarised in the following table.

TABLE 13.

Elementary composition of the acetyl starches.

Starch	C	H	O
Sorghum	47.84	6.65	45.51
Rice	49.43	6.85	43.72
Italian millet	47.62	6.54	45.84
Barley	44.75	7.22	48.03
Corn (Kingsford)	48.47	6.73	44.80
Cassava	47.77	6.37	45.86
Wheat (Ito)	47.17	6.20	46.63
Buckwheat	47.66	6.11	46.23
Corn (Ito)	48.31	6.76	44.93
Arrowroot	47.91	5.98	46.11

The present acetyl starches were insoluble in ethyl, methyl and amylalcohol, swollen in aceton and ethyl acetate, soluble in benzol, chloroform and carbon tetrachloride, easily soluble in pyridin. The content of acetyl group in the compounds was 40.02–45.19% excepting those of the barley and the sorghum. If these values were compared with the theoretical values, the results correspond to the ratio 2–3–3.40. The mean value was nearly 3 and it is possible to say that the compounds were aggregates of triacetyl glucose.

From the two series of results of the acetylation of the starches above described, it was observed that the acetylation by heating

combined more acetyl groups with the starches than the acetylation at the room temperature using pyridin with the exception of the cases of the rice and corn starches which showed almost equal contents of the acetyl group by the two different treatments. The treatment of the starches at the boiling point of the acetic acid anhydride seemed to cause the reaction of the difficultly reacting part of the starches to occur. The heating, therefore, had accelerated the acetylation of the starches. The acetyl content in the acetyl starches and the content of phosphorus in the starches showed some relation; it is possible to say that the acetylation of the starches progressed in inverse proportion to their content of phosphorus. According to SAMEC's consideration that a higher phosphorus content was observed in amylopectin than in amylose, the starches containing much phosphorus or these containing much amylopectin should be less acetylated without heating. The acetylation was influenced seriously by heating in the case of the starches of the cereal plants excepting those of rice and corn. This fact caused the author to consider that amylopectin is contained in the starches of the cereal plants which were more unstable to the action of the heating than the starches of the tubers. The starches of potato and dog-tooth violet did not undergo acetylation without heating, or they produced acetyl starches with very little acetyl groups. The author believes that the starches of the tubers differed markedly from those of the cereal plants in their constitution. From the consideration, the author ventures to say that there were two sorts of starches at least, those of the cereal plants and those of the tubers and that one might classify the starches into the starches of the cereal plant and those of the tubers.

Among the starches of the cereal plants, the starches of rice and corn were relatively stable and the molecular combinations were firm, the starches of barley and sorghum were the most unstable and the molecules were combined loosely. The other cereal starches were between these two extremes. Among the starches of the tubers those of potato and dog-tooth violet were the most stable and that of cassava the most unstable.

§ 5. Benzoylation of the starches

CROSS, BEVAN and BEADLE (26) benzoylated the soluble starch with alkali and benzoyl chloride, SYNIEWSKI (104) obtained the

benzoyl derivatives of the soluble starch. Benzoylation replaces the free hydroxyl groups of the organic substances as in the case of acetylation. Therefore, benzoylation should also yield something in the investigation of the constitution of the starches.

The author carried out benzoylation of his starches with the following processes. Five g of the starch were suspended in 15 c.c. of water. To the suspension were added very slowly 210 c.c. of 10% natrium hydroxide and the starch was thoroughly dissolved. Then as fast as possible, 30 c.c. of benzoyl chloride were added to the solution and the mixture was stirred up very well. In the course of the reaction, heat was liberated and at the end of the reaction, the product of the reaction separated into an white mass. This separated product was washed well on filter paper and was dried at 100°C. in a water oven for 5 hours, then stored in a sulphuric acid desiccator.

The content of the benzoyl group of the product was estimated freeing the benzoyl group as benzoic acid by heating the product with hydrochloric acid in a sealed tube.

TABLE 14.

Benzoyl content of the benzoyl starches.
Two tenths g of each sample was used.

Starch	N/10 NaOH (c.c.)	Benzoyl group (g)	Its content (%)
Potato (Kojima)	8.10	0.08505	42.53
Dog-tooth violet	10.55	0.110775	55.39
Wheat (Kojima)	8.95	0.093975	46.99
Sorghum	9.60	0.10080	50.40
Rice	11.00	0.1155	57.75
Italian millet	10.60	0.1113	55.65
Barley	6.90	0.07245	36.23
Corn (Kingsford)	8.90	0.09345	46.73

The elementary analysis of the benzoyl starches was carried out as described before with the following results.

TABLE 15.

Elementary analysis of the benzoyl starches.

Starch	Sample (mg)	H_2O (mg)	CO_2 (mg)	H (%)	C (%)
Potato (Kojima)	4.155 3.560	1.965 1.640	9.530 8.070	5.290 5.153 5.22	62.56 61.83 62.20
Dog-tooth violet	4.440 5.025	2.275 2.410	9.300 10.550	5.732 5.865 5.55	57.12 57.27 57.20
Wheat (Kojima)	3.060 3.315	1.530 1.565	7.215 7.820	5.594 5.248 5.42	64.30 64.34 64.32
Sorghum	3.780 3.515	2.250 2.000	8.210 7.705	6.643 6.365 6.50	59.23 59.78 59.51
Rice	3.115 4.640	2.190 3.185	7.340 10.960	7.863 7.679 7.77	64.25 64.43 64.34
Italian millet	3.725 3.510	1.945 1.705	8.080 7.745	5.841 5.433 5.64	59.16 60.17 59.66
Barley	3.970 5.475	2.580 3.410	8.870 12.190	7.269 7.131 7.20	60.92 60.70 60.81
Corn (Kingsford)	4.505 3.070	2.585 1.810	10.310 7.000	6.419 6.597 6.51	62.40 62.17 62.29

The results have been summarised in the following table.

TABLE 16.

Elementary composition of the benzoyl starches.

Starch	C	H	O
Potato (Kojima)	62.20	5.22	32.58
Dog-tooth violet	57.20	5.55	37.25
Wheat (Kojima)	64.32	5.42	30.26
Sorghum	59.51	6.50	33.99

TABLE 16. (*Continued*)

Starch	C	H	O
Rice	64.34	7.77	27.89
Italian millet	59.66	5.64	34.70
Barley	60.81	7.20	31.99
Corn (Kingsford)	62.29	6.51	31.20

The benzoylation also seemed to replace the hydroxyl groups of the glucose residues of the starch as in the case of the acetylation. The author calculated the theoretical content of the benzoyl groups of the compound.

TABLE 17.

Theoretical content of the benzoyl groups of the benzoyl starches.

Glucose residue	Benzoyl group	Ratio	Content (%)
1	1	1	37.84
2	3	1.5	46.87
1	2	2	54.14
2	5	2.5	59.68
1	3	3	64.00

Comparing the numbers in Table 14 and Table 17, it is evident that a monobenzoyl compound had been obtained by the benzoylation of the barley starch; an equal mixture of monobenzoyl and dibenzoyl compounds or a compound containing 3 benzoyl groups to 2 glucose residues, was obtained by the benzoylation of the potato, wheat, sorghum and corn starches; a dibenzoyl compound was obtained by the benzoylation of the rice, dog-tooth violet and Italian millet starches. The compound which contained 3 benzoyl groups to 2 glucose residues or the compound whose ratio was 1.5 was the most easily obtained. The results of the acetylation and the benzoylation of the starches had showed the same tendency that the starches which were easily acetylated without heating were also easily

benzoylatable. The relation that the acetylation and the content of phosphorus were inversely proportional was again recognised between the benzoylation and the content of the phosphorus of the starches, excepting the rice starch.

The starches of the tubers, especially the potato starch, were benzoylated with relatively more difficulty than the starches of the cereal plants. Therefore, the starches of the tubers and the starches of the cereal plants seem to be different in constitution and in other points as was seen when the acetylation was carried out, described above in the former part of the investigation.

§ 6. Nitration of the starches

In 1833, BRACONNOT (18) studied the reaction between starch and nitric acid and obtained a nitric acid compound which he named xyloidin. PELOUZE (68), BALLOT (3), KINDT (47), PAYEN (66), REINSCH (77), BÉCHAMP (4), RITTER (78), LIEBEN and REICHARDT (50), BERTHELOT (12), MÜHLHÄUSER (59), WILL and LENZE (113), BROWN and MILLAR (23), SAPOZHNIKOV (96), BERL and SMITH (6), TRAQUAIR (109), BERE and BÜTLER (11), COPE and BARAB (24), SADTLER (81), KESSELER and RÖHM (46), PRINGSHEIM, LEIBOWITZ and SILMANN (73), H. OKADA (65) carried out the nitration of starch. By the action of nitric acid or the mixture of nitric acid and sulphuric acid with the starch, a nitro compound of starch was obtained. The heat of the formation of the compound was estimated. The compound had an explosive power and it decomposed explosively at 194°C. The product was the nitric acid ester of starch and by treatment with a ferrous salt or ferrous chloride, the compound produced starch or soluble starch. The nitrogen content of the compound differed very markedly, according to the investigators, ranging between 6.7% and 14.08%. The form of the combination of the nitro groups with the starch molecule was reported as the mono-, tetra- or the hexanitrate of the starch.

The author proposed the nitration of the starches and carried out the following experiments. To 2 g of the starch were added 20 c.c. of nitric acid of specific gravity 1.5 and 40 c.c. of concentrated sulphuric acid. The mixture was kept still for 2 days. The reaction product was poured into ice water with the greatest care when it was precipitated and was next washed well with water. The material

was dried in the desiccator of diminished pressure over sulphuric acid. The product obtained was a white amorphous mass of markedly explosive power.

The nitrogen content of the product was measured by digestion after GUNNING's modified method, the distillation of the ammonia by the micro KJELDAHL method, and the elementary analysis was carried out by the micro method.

TABLE 18.

Nitrogen content of the nitro-starches.

Starch	Sample (mg)	N/100 HCl (c.c.)	Nitrogen (%)	Mean
Potato (Kojima)	4.530 5.300	3.09 3.59	9.55 9.48	9.52
Dog-tooth violet	3.685 4.480	2.74 3.39	10.41 10.59	10.50
Wheat (Kojima)	3.675 3.120	2.96 2.44	11.27 10.95	11.11
Sorghum	3.870 5.350	2.65 3.66	9.59 9.58	9.58
Rice	3.860 3.230	2.69 2.25	9·76 9.75	9.76
Italian millet	4.970 3.470	3.47 2.37	9.77 9.56	9.67
Barley	2.170 2.150	1.54 1.54	9.93 10.02	9.98
Corn (Kingsford)	4.670 3.690	2.79 2.19	8.36 8.31	8.34

Elementary analysis of the nitro-starches.

Starch	Sample (mg)	H_2O (mg)	CO_2 (mg)	H (%)	C (%)
Potato (Kojima)	3.28) 3.110	1.550 1.535	3.580 3.360	5.285 5.521 5.40	29.77 29.45 29.61
Dog-tooth violet	3.400 2.970	1.300 1.135	3.700 3.205	4.277 4.275 4.28	29.68 29.43 29.55
Wheat (Kojima)	3.650 2.410	1.470 0.920	4.080 2.680	4.505 4.271 4.39	30.49 30.33 30.41

TABLE 18. (*Continued*)

Starch	Sample (mg)	H_2O (mg)	CO_2 (mg)	H (%)	C (%)
Sorghum	3.600	1.370	4.055	4.257	30.72
	3.180	1.220	3.550	4.292	30.45
				4.27	30.58
Rice	2.165	0.855	2.295	4.437	29.73
	4.505	1.780	4.885	4.420	29.56
				4.43	29.64
Italian millet	3.910	1.680	4.250	4.806	29.64
	3.140	1.295	3.490	4.614	30.32
				4.71	29.98
Barley	4.490	1.775	4.850	4.326	28.82
	3.960	1.500	4.175	4.237	28.75
				4.28	28.78
Corn (Kingsford)	3.400	1.380	3.810	4.540	30.56
	3.155	1.220	3.555	4 326	30.73
				4.43	30.65

The results have been summarised in the following table.

TABLE 19.

Elementary composition of the nitro-starches.

Starch	C	H	N	O
Potato (Kojima)	29.61	5.40	9.52	55.47
Dog-tooth violet	29.55	4.28	10.50	55.67
Wheat (Kojima)	30.41	4.39	11.11	54.09
Sorghum	30.58	4.27	9.58	55.57
Rice	29.64	4.43	9.76	56.17
Italian millet	29.98	4.71	9.67	55.64
Barley	28.78	4.28	9.98	56.96
Corn (Kingsford)	30.65	4.43	8.34	56.58

The nitrogen content of the nitro-starches lay between 8.34 11.11% and the results were analogous to those reported formerl The theoretical content of the nitrogen of the compound was calculate by the author as follows.

TABLE 20.

Theoretical content of the nitrogen of the nitro-starches.

Glucose residue	Nitrogen	Ratio	Content (%)
1	1	1	6.23
2	3	1.5	8.89
3	5	1.67	9.54
1	2	2	10.37

Comparing Table 19 and Table 20, the following facts were observed: that the starches of wheat and dog-tooth violet produced dinitro-glucose; that the starch of corn produced a nitro compound of the ratio of 1.5, i.e., a compound containing 3 nitro groups to 2 glucose residues or the mixture of equal quantities of dinitroglucose and mononitroglucose; and that the other starches produced nitro compounds of the ratio of 1.67, i.e., compounds containing 5 nitro groups to 3 glucose residues or mixtures of 2 dinitroglucose and 1 mononitroglucose.

These nitro-starches were insoluble in benzol, chloroform, carbon tetrachloride, amylalcohol and ether, soluble in ethylalcohol, methylalcohol, aceton and pyridin. Two tenhts g of the sample were dissolved in 15 c.c. of pyridin. After 3 hours the rotatory power of the solution was measured by the GOELTZ' LIPPICH polariscope using a natrium lamp as the light source at 18°C.

TABLE 21.

Rotatory powers of the nitro-starches dissolved in pyridin.

Starch	α	$[\alpha]_D^{18°}$
Potato (Kojima)	3.68	138.0
Dog-tooth violet	3.62	135.7
Wheat (Kojima)	3.38	126.8
Sorghum	3.62	135.7
Rice	3.08	115.5
Italian millet	3.43	128.6
Barley	3.14	117.7
Corn (Kingsford)	3.60	135.0

No relations were observed between the rotatory powers and the nitrogen content of the nitro-starches.

When the results of the acetylation and the benzoylation were compared with the results of the nitration of the starches, there were observed no significant relations among them. It could be said, however, that the starches easily acetylated by heating seemed to produce nitro compounds of high nitrogen content. Accordingly it is possible to say that the treatment of the starches with acid, either hot or cold, had effected some changes upon the constitution of the starch molecules. Therefore, full attention had to be paid to the use of acid when the study of the starch molecules was intended.

§ 7. Mechanism of the hydrolysis of the starches by the action of the diastase

By the action of the diastase, the starch is hydrolysed and forms maltose. The mechanism of this hydrolysis of the starch was studied by BROWN and GLENDINNING (22) for the first time. They concluded that the hydrolysis progressed according to the linear function of the reaction time until 36% of the substrate was hydrolysed, then the hydrolysis progressed according to the logarithmic law. LING (51) denied KJELDAHL's "law of proportionality" when the hydrolysis of the starch was carried out with the diastase of dried malt, but FORD (31) observed that the hydrolysis progressed precisely according to the same law. LAER (48) reported that hydrolysis was controlled by the logarithmic law of unimolecular reaction when the initial concentration of the starch was below 4.5%. He observed that the velocity coefficient decreased when the time of the reaction was lengthened. HEYL (38) confirmed that hydrolysis obeyed the logarithmic law, BIEDERMANN (14) experienced that the time required for the hydrolysis of the starch was inversely proportional to the quantity of the enzyme used. SHERMAN, WALKER and CALDWELL (100) reported that the velocity coefficient of the hydrolysis of the potato starch was slightly greater than that of the starch of the cereal plants. LÜERS and WASMUND (54) observed that the hydrolysis obeyed KJELDAHL's "law of proportionality". SYNIEWSKI (104) denied that hydrolysis was a monomolecular reaction. AMBARD (2) reported that the amylolysis did not obey the simple kineitic formula derived from the law of mass action. The present author stated in his

former report (61) that the hydrolysis of the proteins by the action of the enzyme progresses according to the equation

$$\frac{1}{t^{k'}} \cdot \frac{x}{a(a-x)} = k \ .$$

Intending to study the law of the hydrolysis of starch by the action of the diastase, the authors performed the following experiments.

In a thermostat at 40°C., a mixture of the following composition was kept for 5, 10, 20, 40, 80, 160 minutes and for 3–4 days. The last mentioned time was taken as the end of the hydrolysis.

0.5% diastase solution	5 c.c.
1% starch solution	50 c.c.
Buffer solution of pH 5.2 (Phosphate mixture) .	35 c.c.
Water	10 c.c.

At the end of each time, the quantity of the reducing sugar 10 c.c. of each mixture was estimated by BERTLAND's method. One c.c. of the potassium permanganate solution used for the titration was equivalent to 0.00854 mg of copper. The following numbers are the mean of 3–5 determinations.

TABLE 22.

Hydrolysis of the starches by the action of the diastase.

Time (min.)	5	10	20	40	80	160	End
			Potato starch (Kojima)				
$KMnO_4$ (c.c.)	1.1	1.9	3.2	4.0	4.3	4.5	4.85
Cu (mg)	9.39	16.13	27.33	34.16	36.72	38.43	41.42
Maltose (mg)	6.64	13.02	23.55	29.96	32.38	34.00	36.82
%	18.04	35.36	63.97	81.39	87.96	92.37	100.00
			Dog-tooth violet starch				
$KMnO_4$ (c.c.)	1.1	1.9	3.1	3.6	3.85	4.1	4.6
Cu (mg)	9.39	16.13	26.59	30.76	32.88	35.01	39.28
Maltose (mg)	6.64	13.02	22.89	26.76	28.68	30.81	34.76
%	19.10	37.44	65.85	76.98	82.50	88.65	100.00

TABLE 22. (*Continued*)

Time (min.)	5	10	20	40	80	160	End
			Wheat starch (Kojima)				
$KMnO_4$ (c.c.)	1.1	1.8	3.1	3.6	3.9	4.0	4.7
Cu (mg)	9.39	15.37	26.59	30.76	33.31	34.16	40.14
Maltose (mg)	6.64	12.27	22.89	26.76	29.11	29.96	35.54
%	18.68	34.52	64.40	75.30	81.91	84.31	100.00
			Sorghum starch				
$KMnO_4$ (c.c.)	1.1	1.9	2.9	3.4	3.6	3.8	4.4
Cu (mg)	9.39	16.13	24.77	29.04	30.76	32.45	37.58
Maltose (mg)	6.64	13.02	21.08	25.17	26.76	28.30	33.18
%	20.02	39.23	63.53	75.88	80.67	85.31	100.00
			Rice starch				
$KMnO_4$ (c.c.)	1.1	2.0	2.9	3.3	3.5	3.7	4.65
Cu (mg)	9.39	17.08	24.77	28.18	29.89	30.74	39.71
Maltose (mg)	6.64	13.88	21.08	24.38	25.93	26.74	35.15
%	18.89	39.50	59.96	69.36	73.77	76.08	100.00
			Italian millet starch				
$KMnO_4$ (c.c.)	0.4	0.7	1.3	2.4	3.1	3.45	4.2
Cu (mg)	3.42	6.18	11.10	20.50	26.59	29.56	35.87
Maltose (mg)	2.38	4.31	8.30	17.19	22.89	25.63	31.67
%	7.51	13.61	26.20	54.26	72.26	80.91	100.00
			Barley starch				
$KMnO_4$ (c.c.)	1.2	1.8	3.1	3.5	3.8	3.85	5.0
Cu (mg)	10.25	15.37	26.59	29.89	32.45	32.88	42.70
Maltose (mg)	7.45	12.27	22.89	25.93	28.30	28.68	38.00
%	19.61	32.28	60.23	68.23	74.47	75.48	100.00
			Corn starch (Kingsford)				
$KMnO_4$ (c.c.)	1.3	1.9	2.9	3.4	3.7	3.8	4.8
Cu (mg)	11.10	16.13	24.77	29.04	30.74	32.45	40.99
Maltose (mg)	8.30	13.02	21.08	25.17	26.74	28.30	36.39
%	22.81	35.77	57.92	69.16	73.48	77.76	100.00
			Potato starch (Ito)				
$KMnO_4$ (c.c.)	1.1	1.95	3.18	3.5	3.8	3.9	4.6
Cu (mg)	9.39	16.65	27.16	28.89	32.45	33.31	39.28
Maltose (mg)	6.64	13.75	23.33	25.93	28.30	29.11	34.76
%	19.10	39.56	67.13	74.59	81.41	83.73	100.00

TABLE 22. (*Continued*)

Time (min.)	5	10	20	40	80	160	End
			Cassava starch				
$KMnO_4$ (c.c.)	1.4	2.0	3.28	3.6	3.75	3.95	4.9
Cu (mg)	11.96	17.08	28.01	30.76	32.03	33.75	41.85
Maltose (mg)	9.11	13.88	24.28	26.76	28.73	29.53	37.23
%	24.47	37.30	65.22	71.90	77.20	79.32	100.00
			Wheat starch (Ito)				
$KMnO_4$ (c.c.)	1.0	1.8	2.7	3.1	3.5	3.8	4.7
Cu (mg)	8.54	15.37	23.06	26.59	29.89	32.45	40.14
Maltose (mg)	7.80	12.27	19.54	22.89	25.93	28.30	35.54
%	21.95	34.52	54.98	64.40	72.97	79.64	100.00
			Buckwheat starch				
$KMnO_4$ (c.c.)	1.18	2.05	3.1	3.2	3.5	3.65	4.6
Cu (mg)	10.08	17.51	26.59	27.33	29.89	31.17	39.28
Maltose (mg)	7.28	14.31	22.89	23.55	25.93	27.16	34.76
%	20.94	41.16	65.85	67.75	74.59	78.12	100.00
			Corn starch (Ito)				
$KMnO_4$ (c.c.)	1.05	1.78	2.9	3.23	3.5	3.75	4.7
Cu (mg)	8.97	15.20	24.77	27.58	29.89	32.03	40.14
Maltose (mg)	6.26	12.10	21.08	23.78	25.93	28.73	35.54
%	17.62	34.05	59.30	66.91	72.97	80.85	100.00
			Arrowroot starch				
$KMnO_4$ (c.c.)	1.1	1.9	3.19	3.55	3.8	4.0	4.9
Cu (mg)	9.39	16.13	27.18	30.32	32.45	34.16	41.85
Maltose (mg)	6.64	13.02	23.42	26.32	28.30	29.96	37.23
%	17.84	34.97	62.92	70.71	76.03	80.50	100.00

Taking the logarithms of the author's equation, the following equation was obtained.

$$-k' \log t + \log \frac{x}{a(a-x)} = \log k \ ,$$

or

$$\log k + k' \log t - \log \frac{x}{100(100-x)} = 0 \ .$$

Taking the hydrolysis of the starch of the potato (KOJIMA) as the example, the observation equations were formed as follows.

$$\log k + k'\,0.6990 + 2.6574 = 0$$
$$\log k + k'\,1.0000 + 2.2620 = 0$$
$$\log k + k'\,1.3010 + 1.7507 = 0$$
$$\log k + k'\,1.6021 + 1.3591 = 0$$
$$\log k + k'\,1.9031 + 1.1363 = 0$$
$$\log k + k'\,2.2041 + 0.9170 = 0$$

The normal equations were formed and they were solved in the usual way with the following results.

$$6 \log k + 8.7093\,k' + 10.0825 = 0$$
$$8.7093 \log k + 14.2277\,k' + 12.7582 = 0$$
$$k' = 1.1837$$
$$\log k = -3.3986 = \bar{4}.6014$$
$$k = 0.0003994$$

Similar calculations according to the method of least squares were carried out upon the other experimental results showed in Table 22.

TABLE 23.

The two constants of the equation calculated from the numbers of Table 22.

Starch	k	k'	Starch	k	k'
Potato (Kojima)	0.0003994	1.1837	Corn (Kingsford)	0.0004222	1.0260
Dog-tooth violet	0.0006369	0.9991	Potato (Ito)	0.0008612	0.8853
Wheat (Kojima)	0.0006969	0.9362	Cassava	0.001289	0.7368
Sorghum	0.0008145	0.9032	Wheat (Ito)	0.0009672	0.7608
Rice	0.001101	0.7365	Buckwheat	0.001283	0.7171
Italian millet	0.00009645	1.2593	Corn (Ito)	0.0007695	0.8327
Barley	0.0009654	0.7606	Arrowroot	0.0008170	0.8409

The percentages of the hydrolysis of the starch were calculated by the use of the obtained constants. They were compared with those obtained by the experiments and arranged in the following table.

TABLE 24.

Percentages of the hydrolysis of the starches calculated and observed.

Time (min.)	5	10	20	40	80	160
			Potato starch (Kojima)			
Observed	18.04	35.36	63.97	81.39	87.96	92.37
Calculated	21.16	37.87	58.07	75.89	87.72	94.20
Difference	−3.12	−2.51	5.90	5.50	0.24	−1.83
			Dog-tooth violet starch			
Observed	19.10	37.44	65.85	76.98	82.50	88.65
Calculated	24.13	38.86	55.97	71.74	83.54	91.02
Difference	−5.03	−1.42	9.88	5.24	−1.04	−2.37
			Wheat starch (Kojima)			
Observed	18.68	34.52	64.40	75.30	81.91	84.31
Calculated	23.93	37.57	53.53	68.80	80.83	88.97
Difference	−5.25	−3.05	10.87	6.50	1.08	−4.66
			Sorghum starch			
Observed	20.02	39.23	63.53	75.88	80.67	85.31
Calculated	25.84	39.46	54.93	69.51	81.00	88.85
Difference	−5.82	−0.23	8.60	6.37	−0.33	−3.54
			Rice starch			
Observed	18.89	39.50	59.96	69.36	73.77	76.08
Calculated	26.47	37.50	40.99	62.48	73.50	82.21
Difference	−7.58	2.00	9.97	5.99	0.27	−6.13
			Italian millet starch			
Observed	7.51	13.61	26.20	54.26	72.26	80.91
Calculated	6.82	14.91	29.55	50.12	70.63	85.19
Difference	0.69	−1.30	−3.35	4.14	1.63	−4.28
			Barley starch			
Observed	19.61	32.28	60.23	68.23	74.47	75.48
Calculated	24.71	35.74	48.51	61.49	73.01	82.08
Difference	−5.10	−3.46	11.72	6.74	1.46	−6.60

TABLE 24. *(Continued)*

Time (min.)	5	10	20	40	80	160
			Corn starch (Kingsford)			
Observed	22.81	35.77	57.92	69.16	73.48	77.76
Calculated	18.05	30.95	47.72	65.02	79.10	88.51
Difference	4.76	4.76	10.20	4.14	−5.62	−10.75
			Potato starch (Ito)			
Observed	19.10	39.56	67.13	74.59	81.41	83.73
Calculated	26.36	39.80	55.00	69.29	80.65	88.50
Difference	−7.26	−0.24	12.13	5.30	0.76	−4.77
			Cassava starch			
Observed	24.47	37.30	65.22	71.90	77.20	79.32
Calculated	29.67	41.28	53.94	66.14	77.31	84.43
Difference	5.20	−3.98	11.28	4.76	−0.11	−5.11
			Wheat starch (Ito)			
Observed	21.95	34.52	54.98	64.40	72.98	79.64
Calculated	24.76	35.80	48.58	61.15	73.07	82.13
Difference	−2.81	−1.28	6.40	2.85	−0.10	−2.49
			Buckwheat starch			
Observed	20.94	41.16	65.85	67.75	74.59	78.12
Calculated	28.92	40.09	50.25	64.39	74.83	83.01
Difference	−7.98	1.07	15.60	3.36	−0.24	−4.89
			Corn starch (Ito)			
Observed	17.62	34.05	59.30	66.91	72.97	80.85
Calculated	22.71	34.36	48.25	62.42	74.73	84.04
Difference	−5.09	−0.31	11.05	4.49	−1.74	−3.19
			Arrowroot starch			
Observed	17.84	34.97	62.92	70.71	76.03	80.50
Calculated	24.02	36.15	50.35	64.51	76.50	85.35
Difference	−6.18	−1.18	12.57	6.20	−0.47	−4.85

The values of k of the equation were between 0.0006 and 0.0013, with the exceptionally small value of 0.000096 for the Italian millet starch. This starch seemed to have a great resistance to the action

of the diastase, but the cause of such a great resistance could not be made clear by the present investigations.

Taking the values of log k as ordinates and the values of k′ as abscissae, the author obtained a straight line in graph. This fact coincides with the results when the proteins are hydrolysed. In the case of the hydrolysis of the proteins, the values of log k and k′ of the 10% natrium chloride solution soluble proteins, those of the 70% alcohol soluble proteins and those of the 0.2% natrium hydroxide solution soluble proteins were determined all to graph as straight lines. With the exception of the values of the Italian millet starch, the author calculated the two constants of the equation

$$y = ax + b,$$

by means of the method of least squares as follows.

Observation equations.

$$\begin{aligned}
-3.3986 &= a\,1.1837 + b \quad \text{or} \quad & b + 1.1837\,a + 3.3986 &= 0 \\
-3.1959 &= a\,0.9991 + b & b + 0.9991\,a + 3.1959 &= 0 \\
-3.1567 &= a\,0.9362 + b & b + 0.9362\,a + 3.1567 &= 0 \\
-3.0981 &= a\,0.9032 + b & b + 0.9032\,a + 3.0891 &= 0 \\
-2.9584 &= a\,0.7365 + b & b + 0.7365\,a + 2.9584 &= 0 \\
-3.0153 &= a\,0.7606 + b & b + 0.7606\,a + 3.0153 &= 0 \\
-3.3745 &= a\,1.0260 + b & b + 1.0260\,a + 3.3745 &= 0 \\
-3.0649 &= a\,0.8853 + b & b + 0.8853\,a + 3.0649 &= 0 \\
-3.1138 &= a\,0.8327 + b & b + 0.8327\,a + 3.1138 &= 0 \\
-3.0878 &= a\,0.8409 + b & b + 0.8409\,a + 3.0878 &= 0 \\
-2.8898 &= a\,0.7368 + b & b + 0.7368\,a + 2.8898 &= 0 \\
-3.0145 &= a\,0.7608 + b & b + 0.7608\,a + 3.0145 &= 0 \\
-2.8916 &= a\,0.7171 + b & b + 0.7171\,a + 2.8916 &= 0
\end{aligned}$$

Normal equations

$$13\,b + 11.3189\,a + 40.2509 = 0$$
$$11.3189\,b + 10.0951\,a + 35.2948 = 0.$$

Solving

$$a = -1.0378$$
$$b = -2.1989.$$

Therefore

$$\log k = -1.0378\,k' - 2.1989.$$

Generally speaking, if the mechanism of the hydrolysis by the enzyme were expressed by the equation

$$\frac{1}{t^{k'}} \cdot \frac{x}{a(a-x)} = k\,,$$

it is possible to deduce that the relations between log k and k′ could be expressed by an equation of a straight line.

§ 8. Viscosities of the solutions of the starches

The viscosities of the solutions of the starches have been investigated by many authors. SAMEC reported his detailed studies in his book "Kolloidchemie der Stärke"(83). In that book were described the relations between the viscosity and the concentrations of the solution of the starch, the influences of temperature and time of heating in the preparation of the solution of the starch upon the viscosity, the changes in the viscosity of the solution of the starch when it was stood for a long period at room temperature, the influences of the acids, the alkalies and the salts upon the viscosity of the solution of the starch and the viscosities as characteristics of the starches of various kinds of plants.

Studying the viscosities of the solutions of his starches, the author obtained the following results. To given quantities of the starch were added 40 c.c. of water; the mixture was heated for 2 hours in an autoclave at the pressure of $2\frac{1}{2}$ kg/cm^2; after 1 hour's standing the mixture was taken out and cooled to room temperature. The solution was made up to 50 c.c. and the flowing time of the solution using an Ostwald's viscosimeter was measured at 20°C. The flowing time of water was taken as 1 and the specific viscosity of the solution of the starch was calculated. The following are the mean values of more than 2 experiments.

TABLE 25.

Specific viscosities of the solutions of the starches.

Starches	Concentrations of solution			
	0.5%	1.0%	2.0%	4.0%
Potato (Kojima)	1.054	1.236	2.218	6.363
Dog-tooth violet	1.127	1.400	2.509	7.000

TABLE 25. (*Continued*)

Starches	Concentrations of solution			
	0.5%	1.0%	2.0%	4.0%
Wheat (Kojima)	1.091	1.327	2.636	13.600
Sorghum	1.327	2.090	7.654	53.390
Rice	1.273	1.963	6.908	—
Italian millet	1.309	2.018	6.527	—
Barley	1.109	1.309	1.781	9.745
Corn (Kingsford)	1.181	1.545	3.545	26.080
Potato (Ito)	1.115	1.231	1.481	1.788
Cassava	1.212	1.442	1.981	3.770
Wheat (Ito)	1.134	1.231	1.461	2.231
Buckwheat	1.134	1.269	1.577	2.615
Corn (Ito)	1.173	1.326	1.923	4.134
Arrowroot	1.115	1.231	1.423	1.942

By the same method described before, 2% solution of the starch was prepared and the viscosities of the solution were measured at various intervals of time. The same calculations were performed; the results have been arranged in Table 26.

TABLE 26.

Changes of the viscosity of the solution of the starches by aging.

Starch	Time of aging (day)							
	0	1	2	3	4	5	6	7
Potato (Kojima)	2.218	2.218	2.000	1.690	1.454	1.454	1.363	1.363
Dog-tooth violet	2.509	2.491	2.400	2.072	1.891	1.746	1.618	1.600
Wheat (Kojima)	2.636	2.273	1.636	1.327	1.254	1.218	1.199	1.181
Sorghum	7.654	7.308	7.199	6.853	6.853	6.053	5.418	4.782
Rice	6.908	6.689	7.399	7.872	7.800	6.145	4.544	3.854
Italian millet	6.527	6.307	9.036	12.220	10.580	8.762	8.035	6.853
Barley	1.781	1.836	1.927	2.018	2.109	2.145	2.200	2.254
Corn (Kingsford)	3.545	3.510	3.545	3.470	4.490	3.363	3.309	3.309

TABLE 26. *(Continued)*

Starch	Time of aging (day)							
	0	1	2	3	4	5	6	7
Potato (Ito)	1.481	1.500	1.481	1.481	1.481	1.442	—	—
Cassava	1.981	2.019	2.000	1.981	1.981	1.981	—	—
Wheat (Ito)	1.462	1.500	1.481	1.481	1.462	1.500	—	—
Buckwheat	1.577	1.596	1.577	1.577	1.577	1.596	—	—
Corn (Ito)	1.923	1.942	1.846	1.904	1.923	1.942	—	—
Arrowroot	1.423	1.423	1.423	1.404	1.404	1.423	—	—

According to the two tables, it may be seen that the highest viscosity was observed in the case of the sorghum starch instead of the potato. After the sorghum followed the starches of rice and Italian millet. As to the potato starch it could not be said that its viscosity was a higher one. By aging of the solution of the starch, the viscosity reached its maximum in 1–4 days, whereafter a decrease of the viscosity was observed. The barley starch alone showed increasing viscosity as a result of aging, within the limits of the present investigation.

§ 9. Electrical conductivity of the solution of the starches

FOUARD (33) reported that the solution of the starch polymerised to granular starch particles and the electrical conductivity of the solution increased when the solution was kept for a long period. SAMEC (82), SAMEC and VON HOEFFT (90), also SAMEC and HAERDTL (89) reported that the electrical conductivity of the solution of the starch was increased by the aging of the solution, a phenomena opposite to the viscosity of the solution, that by the electrodialysis of the solution of the starch the electric conducting fraction of the solution had precipitated and that there was no direct relation between the conductivity and the phosphorus content of the starch. TIEBACKX (108) proposed that the heating and the aging of the solution of the starch made the amylopectin decompose increasing the electrical conductivity of the solution.

The author carried out the following experiments. One g of the starch and 40 c.c. of water were taken into an Erlenmeyer flask

of hard glass, the material was heated for one hour in an autoclave at 120°C. (or 1.3 kg/cm²), after cooling of the matter, the mixture was made up to 50 c.c. with water. The electrical conductivity of the obtained 2% solution of the starch was measured at 18°C. using a cell whose cell constant was 0.6329.

TABLE 27.

Electrical conductivity of the solutions of the starches.

Starch	R	x	K	Mean
Potato (Kojima)	13000 13300	41.4 41.8	3.440×10^{-5} 3.417	3.429×10^{-5}
Dog-tooth violet	13000 13300	38.1 38.5	2.997 2.979	2.988
Wheat (Kojima)	13000 13300	41.7 42.4	3.482 3.502	3.492
Sorghum	13000 13300	35.9 36.5	2.727 2.733	2.730
Rice	13000 13300	34.9 35.5	2.610 2.619	2 615
Italian millet	13000 13300	30.3 30.5	2.115 2.088	2.102
Barley	13000 13300	15.4 15.9	0.886 0.900	0.893
Corn (Kingsford)	13000 13300	19.2 19.6	1.157 1.160	1.159
Potato (Ito)	13000 13300	31.0 31.6	2.189 2.198	2.193
Cassava	13000 13300	11.5 12.0	0.633 0.649	0.641
Wheat (Ito)	13000 13300	11.4 11.8	0.627 0.637	0.632
Buckwheat	13000 13300	16.0 16.5	0.927 0.940	0.934
Corn (Ito)	13000 13300	11.8 12.0	0.652 0.649	0.650
Arrowroot	13000 13300	20.0 20.3	1 217 1.212	1.215

No direct relation was observed between the electrical conductivity of the solution of the starch and the phosphorus content as had been already reported by HAERDTL. Also no direct relations were observed between the conductivity and the ash content, nor between the conductivity and the nitrogen content of the starch.

On the whole, however, the conductivity of the solution of the starch seemed to be increased when the content of ash, phosphorus or nitrogen of the starch was increased.

§ 10. Influence of salts added to the solutions of the starches upon the viscosity of the solutions

M. SAMEC(83) summarised in his book the results of many investigations concerning the influence of the salts added to the solutions of the starches upon their viscosity. The viscosity of the starch solutions was diminished by the addition of salts to the solution when the quantities of the salts were small. However, there was observed a tendency for the viscosity of a starch solution to increase when the quantity of the salts added was increased.

As one of the reasons for this phenomena, SAMEC had stated that the amylopectin of the starch was destroyed by the addition of the salt and therefore the separation of the phosphoric acid from the starch which combined in the form of an ester was observed by the action of the salt. According to SAMEC's view, the amylopectin of the starch was the sole factor influencing the viscosity of the starch solutions.

To 1 g of the starch were added 25 c.c. of salt solution of given concentration and 15 c.c. of water. The mixture was heated for 1 hour at 120°C. in an autoclave. When the solution was cooled, it was made up to 50 c.c. by the addition of water. The viscosity of the obtained solution was measured at 20°C. by means of an OSTWALD's viscosimeter. The following table shows the relative viscosity of the various starch salt solutions when the viscosity of water was taken as unit.

TABLE 28.

Influence of the salts upon the viscosity of the solutions of the starches.

Concentration of salt (N)	Potato (Kojima)	Dog-tooth violet	Wheat (Kojima)	Sorghum	Rice	Italian millet	Barley	Corn (Kingsford)
				NaCl				
0	6.759	5.999	8.352	6.222	6.296	6.778	4.130	4.167
2.10^{-4}	7.482	6.296	8.519	6.094	6.074	6.463	3.925	4.222
1.10^{-3}	5.981	6.037	6.612	5.964	5.481	6.092	3.833	4.352
5.10^{-3}	5.204	5.630	5.852	5.463	5.759	7.241	3.722	4.370
$1\ 10^{-2}$	5.000	5.463	5.723	5.3[illegible]9	5.815	7.389	3.611	4.278
2.10^{-2}	5.075	5.500	5.555	5.222	6.537	6.688	3.462	4.148
4.10^{-2}	5.147	5.186	5.538	5.204	6.037	7.166	3.426	4.200
1.10^{-1}	5.222	5.723	6.074	5.518	6.074	7.052	3.334	4.095
				KCl				
0	—	5.694	8.555	6.981	—	6.037	—	4.130
2.10^{-4}	—	5.630	8.056	6.852	—	7.092	—	4.204
1.10^{-3}	—	5.888	6.759	6.371	—	7.685	—	4.296
5.10^{-3}	—	5.684	5.944	6.648	—	14.570	—	4.352
1.10^{-2}	—	5.352	5.833	5.277	—	8.500	—	4.148
2.10^{-2}	—	5.093	5.852	5.705	—	8.389	—	4.000
4.10^{-2}	—	4.777	5.852	5.888	—	6.944	—	4.095
1.10^{-1}	—	4.612	5.759	5.630	—	7.148	—	4.037
				$CaCl_2$				
0	—	5.500	8.796	5.999	—	6.240	—	4.130
2.10^{-4}	—	5.852	8.592	6.889	—	6.110	—	4.000
1.10^{-3}	—	5.408	6.371	6.889	—	7.759	—	4.111
5.10^{-3}	—	4.315	5.630	6.704	—	6.685	—	3.870
1.10^{-2}	—	4.148	5.593	5.964	—	5.759	—	3.833
2.10^{-2}	—	3.778	5.075	5.666	—	5.726	—	3.759
4.10^{-2}	—	3.649	4.815	5.500	—	5.723	—	3.519
1.10^{-1}	—	3.389	4.205	3.963	—	5.241	—	3.037
				$BaCl_2$				
0	—	5.538	8.537	6.037	—	5.075	—	4.278
2.10^{-4}	—	4.648	6.907	6.054	—	6.054	—	4.426
1.10^{-3}	—	4.648	6.317	6.555	—	6.482	—	4.833
5.10^{-3}	—	4.204	6.110	7.131	—	6.352	—	4.148
1.10^{-2}	—	4.037	5.779	6.573	—	8.426	—	4.037
2.10^{-2}	—	3.537	5.259	6.832	—	7.111	—	3.759
4.10^{-2}	—	3.833	5.222	6.092	—	6.537	—	3.778
1.10^{-1}	—	2.648	4.852	5.518	—	6.630	—	3.555

The values when the concentration of the salts added was zero were taken as 100 and the relative values of each concentration of the salts added were calculated as shown in the following table.

TABLE 29.

Relative values of the viscosities of the starch solutions taking as 100 the values obtained when the concentration of the salt added was zero.

Concentration of salt (N)	Potato (Kojima)	Dog-tooth violet	Wheat (Kojima)	Sorghum	Rice	Italian millet	Barley	Corn (Kingsford)
				NaCl				
0	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2.10^{-4}	110.69	104.95	102.00	97.91	96.47	95.35	95.04	101.32
1.10^{-3}	88.49	100.63	97.17	95.85	87.05	89.88	92.81	104.44
5.10^{-3}	76.99	93.85	70.07	87.80	91.47	106.83	90.12	104.87
1.10^{-2}	73.98	91.06	68.52	86.61	92.36	109.01	87.43	102.66
2.10^{-2}	75.08	91.68	66.51	83.93	103.83	98.67	83.83	99.54
4.10^{-2}	76.15	86.45	66.31	83.64	95.64	105.72	82.95	100.79
1.10^{-1}	77.26	95.40	72.72	88.69	96.47	104.04	80.73	98.27
				KCl				
0	—	100.00	100.00	100.00	—	100.00	—	100.00
2.10^{-4}	—	99.05	94.17	98.15	—	117.47	—	101.79
1.10^{-3}	—	103.59	79.01	91.23	—	127.30	—	104.02
5.10^{-3}	—	100.00	69.48	95.23	—	241.34	—	105.33
1.10^{-2}	—	94.16	68.18	75.59	—	140.80	—	100.43
2.10^{-2}	—	89.60	68.40	81.72	—	138.96	—	96.85
4.10^{-2}	—	84.04	68.40	84.34	—	115.02	—	99.15
1.10^{-1}	—	81.14	67.32	80.65	—	118.40	—	97.75
				$CaCl_2$				
0	—	100.00	100.00	100.00	—	100.00	—	100.00
2.10^{-4}	—	106.40	97.68	114.84	—	97.92	—	96.85
1.10^{-3}	—	98.33	72.43	114.84	—	124.34	—	99.54
5.10^{-3}	—	78.45	64.01	111.75	—	107.13	—	93.70
1.10^{-2}	—	75.42	63.59	99.42	—	92.29	—	92.81
2.10^{-2}	—	68.69	57.70	94.45	—	94.97	—	91.02
4.10^{-2}	—	66.34	54.74	91.68	—	91.71	—	85.21
1.10^{-1}	—	61.62	47.79	66.06	—	83.99	—	73.54

TABLE 29. (*Continued*)

Concentration of salt (N)	Potato (Kojima)	Dog-tooth violet	Wheat (Kojima)	Sorghum	Rice	Italian millet	Barley	Corn (Kingsford)
				$BaCl_2$				
0	—	100.00	100.00	100.00	—	100.00	—	100.00
2.10^{-4}	—	83.93	80.91	100.28	—	106.12	—	103.46
1.10^{-3}	—	83.93	73.98	108.58	—	113.62	—	101.28
5.10^{-3}	—	75.91	71.57	118.12	—	111.34	—	96.96
1.10^{-2}	—	72.90	67.69	108.88	—	147.69	—	94.37
2.10^{-2}	—	63.87	61.60	113.17	—	124.64	—	87.87
4.10^{-2}	—	69.21	61.17	100.91	—	114.58	—	88.31
1.10^{-1}	—	47.82	56.83	91.40	—	116.21	—	83.10

Considering from the values of the table, it is to be observed that the effects of the addition of salts to the solution of the starches were in two directions, one of which was that when the concentration of the salt added was low, the viscosity of the solutions of the starches was increased by the addition and the other was that when the concentration of the salt added became high, the viscosity of the solution was decreased generally. The former effect was observed in the case of the starches of potato, dog-tooth violet, wheat and corn by the addition of NaCl, in the cases of sorghum, Italian millet and corn with KCl, in those of dog-tooth violet, Italian millet and corn with $CaCl_2$ and in those of sorghum, Italian millet and corn with $BaCl_2$. In the case of the Italian millet starch by the addition of NaCl, KCl $BaCl_2$, the viscosity of the solutions became greater with the increase in the concentration of the salts added. These were considered as exceptional and interesting cases by the author. The starches of the potato, dog-tooth violet, wheat, barley and corn had decreased their viscosity with the increasing addition of the salts and the decreases became greater, when the quantities of the salts added were increased.

Comparing the effects of the cations added, the effects of the natrium ion were the smallest and the effects were increased in the order, kalium, barium and then calcium ion. These facts coincide well with HOFMEISTER's series for colloidal solution of gelatin.

In general, the influences of the salts upon the viscosities of the solutions of the starches may be summarised as follows. When the concentration of the salt was low, the viscosity of the solutions of some starches were increased, but when the concentration of the salt was increased, the viscosity of the solutions was decreased in all cases of the starches used.

§ 11. Gold value of the starches

Starch solution showed the properties of a hydrophile colloid as reported by many authors. Therefore, it was thought to effect the protective action in respect to the other colloid. The gold value of the starch as the protective colloid was reported as 5.00 for wheat starch and 25.00 for potato starch and 6.00–20.00 for dextrine by J. ALEXANDER (1). SAMEC (84) and ZSIGMONDY (115) had also reported similar values. W. BILTZ (15) reported that the gold value of dextrine increased according to the diminution of the molecular weight of the dextrines or in other words protective action of the dextrines decreased concordantly with the diminution of their molecular weight. However, M. SAMEC and M. MINAEFF (94) obtained opposite results. The reason for the two contradictory results was reported by SAMEC as lying in the difference of the methods of their investigations.

The author proposing to determine the gold values of his starches carried out the following experiments. Six g of gold chloride were dissolved in 1 L. of water. To 150 c.c. of water were added 2.5 c.c. of the gold solution and 0.9 c.c. of 0.2 N potassium carbonate solution. The mixture was boiled, the heating was stopped at once and 0.9 c.c. of the solution of formaline was added with vigorous stirring. After 2–3 minutes, rosa gold colloidal solution was obtained. The water used in the process was redistilled water obtained by the use of a pure tin tube. The formaline solution was prepared by mixing 100 c.c. of water and 1 c.c. of distilled formaline which was collected at 94–96.5°C. The solution of the starch was prepared with redistilled water as a 1% solution heating for 1 hour under the pressure of 1.3 kg per sq. cm. To 10 c.c. of the gold solution were added the given quantities of the starch solution. To the mixture was then added 1 c.c. of 10% natrium chloride solution and the changes in the colour of the solution were observed. The colour

of the solution became violet when the quantity of the starch added was other than the values described in the following table. Thus the author was able to show that the protective action of the starch upon the gold solution had an optimum quantitative limit.

TABLE 30.

The gold value of the starch.

Potato starch (Kojima)	12	Rice starch	11–12
Dog-tooth violet starch	2–3	Italian millet starch	7
Wheat starch (Kojima)	8	Barley starch	4
Sorghum starch	13	Corn starch (Kingsford)	4

§ 12. Heat of combustion of the starches

The heat of combustion of the starch was reported by BLOEMENDAL (16) as 4000–4027 cal. and by BERTHELOT and VIEILLE (13) as 4228 cal. and 4183 cal. RECHENBERG (76) reported that it was 4448 cal. in rice starch. TADOKORO and collaborators (106) determined the heat of combustion of the starches of common and glutinous rice and reported them as 4262–3893 cal. They also reported that the values of the common rice starches were higher than those of the other.

Considering that the heat of combustion of the starch might differ according to differences in mode of formation of the starch and according to the differences of the plant, the author carried out the estimation of the heat of combustion using ATWATER's bomb calorimeter. The results obtained have been arranged in Table 31.

TABLE 31.

Heat of combustion of the starches.

Starch	Sample (g)	Heat evolved	Heat for 1 g	Dry matter	Mean
Potato (Kojima)	0.4522 0.6076	1569.79 2088.96	3472 3439	3911 3874	3892 cal.
Dog-tooth violet	0.4673 0.5439	1643.53 1890.45	3571 3476	3988 3942	3965

TABLE 31. (*Continued*)

Starch	Sample (g)	Heat evolved	Heat for 1 g	Dry matter	Mean
Sorghum	0.6781 0.5416	2405.84 1895.87	3548 3501	3897 3846	3872 cal.
Rice	0.8633 0.6704	2999.96 2328.77	3474 3472	3909 3908	3909
Italian millet	0.4393 0.4941	1640.13 1809.51	3733 3662	3993 3917	3955
Barley	0.7220 0.9800	2501.65 2366.98	3470 3481	3809 3821	3815
Corn (Kingsford)	0.5528 0.8275	1909.59 2830.83	3446 3421	3978 3949	3963
Wheat (Kojima)	0.4002 0.6499 0.5903	1344.49 2177.33 1973.83	3360 3351 3345	3942 3930 3922	3931

The heat of combustion of the starches averaged about 3900 calories. The author did not find any difference according to the method of the formation of the starches, i.e. any difference of the heat of combustion between the starches formed in the part of a plant of above the ground and those in the part of a plant underground. The heat of combustion was the greatest in the dog-tooth violet starch and followed those of corn, Italian millet, wheat, rice, potato, sorghum and barley.

§ 13. Adsorption of iodine by the starch granules

Studies of the chemical and physico-chemical reactions between iodine and the starch have been reported abundantly from the early time. SAMEC described in his book (85) the coloring and the decoloring of the starch by the action of iodine, the effects of heating and drying upon the starch-iodine reaction and the properties of the starch-iodine products. He discussed the quantitative relations between starch and iodine and observed that the starch-iodine products were thought to be one of the chemical compounds or the solid solution of iodine in starch or the adsorbed products of the two components, whose distinction he thought extremely difficult.

The author (61) has studied the adsorption of iodine by barley starch and calculated the values of the two constants of FREUNDLICH's

adsorption isotherms. In the present investigation, in order further to study the same matter and to calculate the same constants, the following experiments were carried out.

To each 0.5 g of the starches were added 20 c.c. of about N/10, N/25, N/50, N/75, N/100 and N/200 iodine potassium iodide solutions. The mixture was shaken for 30 minutes by means of the shaking machine. It was stood for more 30 minutes and the adsorption reached equilibrium. It was then centrifuged for the purpose of separating the starches; the quantities of iodine remaining in 10 c.c. of the supernatant solution were titrated with the standard solution of natrium thiosulphate. The results were converted to the basis of 1 g of the starch as follows.

TABLE 32.

Adsorption of iodine by the starches.

	Iodine remained C (mg)	Adsorbed x (mg)	log C	log x
		Potato starch (Kojima)		
1 (About N/200)	0.49	23.95	$\bar{1}$.69020	1.37931
2 (,, N/100)	5.74	40.70	0.75891	1.60959
3 (,, N/75)	11.36	52.18	1.05538	1.71750
4 (,, N/50)	28.96	68.80	1.46180	1.83759
5 (,, N/25)	70.02	120.61	1.84522	2.08138
6 (,, N/10)	271.77	214.59	2.43420	2.33161
		Dog-tooth violet starch		
1 (About N/200)	0.61	23.83	$\bar{1}$.78533	1.37712
2 (,, N/100)	6.11	40.33	0.78604	1.60563
3 (,, N/75)	11.61	51.93	1.06483	1.71542
4 (,, N/50)	32.26	65.50	1.50866	1.81624
5 (,, N/25)	76.99	123.64	1.88643	2.09216
6 (,, N/10)	273.24	213.12	2.43635	2.32862
		Wheat starch (Kojima)		
1 (About N/200)	0.98	23.56	$\bar{1}$.99123	1.37033
2 (,, N/100)	7.09	39.35	0.85065	1.59494
3 (,, N/75)	13.08	50.46	1.11661	1.70295
4 (,, N/50)	32.85	65.01	1.51521	1.81298
5 (,, N/25)	78.70	111.93	1.89597	2.04895
6 (,, N/10)	280.08	206.28	2.44728	2.31446

TABLE 32. (*Continued*)

	Iodine remained C (mg)	Adsorbed x (mg)	log C	log x
		Sorghum starch		
1 (About N/200)	2.93	21.51	0.46687	1.33264
2 (,, N/100)	10.87	35.57	1.03623	1.55108
3 (,, N/75)	14.30	49.24	1.15534	1.69232
4 (,, N/50)	23.58	74.18	1.37254	1.87029
5 (,, N/25)	36.17	154.46	1.55835	2.18881
6 (,, N/10)	252.83	233.53	2.40283	2.36834
		Rice starch		
1 (About N/200)	1.22	23.22	0.08636	1.36586
2 (,, N/100)	6.97	39.47	0.84323	1.59627
3 (,, N/75)	12.22	51.32	1.08707	1.71029
4 (,, N/50)	26.66	71.10	1.42586	1.85187
5 (,, N/25)	67.94	122.69	1.83213	2.08880
6 (,, N/10)	268.59	217.77	2.42909	2.33800
		Italian millet starch		
1 (About N/200)	0.24	24.20	$\bar{1}$.38021	1.38382
2 (,, N/100)	3.67	42.77	0.56467	1.63114
3 (,, N/75)	6.97	56.57	0.84323	1.75259
4 (,, N/50)	19.56	78.20	1.29137	1.89321
5 (,, N/25)	56.95	133.68	1.75549	2.12607
6 (,, N/10)	259.31	227.05	2.41382	2.35612
		Barley starch		
1 (About N/200)	0.24	24.20	$\bar{1}$.38021	1.38382
2 (,, N/100)	1.89	44.55	0.27646	1.64885
3 (,, N/75)	5.87	57.67	0.76864	1.76095
4 (,, N/50)	19.80	77.96	1.29667	1.89187
5 (,, N/25)	53.77	136.86	1.73054	2.13627
6 (,, N/10)	275.32	211.04	2.43984	2.32436
		Corn starch (Kingsford)		
1 (About N/200)	0.73	23.71	$\bar{1}$.86332	1.37493
2 (,, N/100)	6.11	40.33	0.78604	1.60563
3 (,, N/75)	11.16	52.38	1.04766	1.71917
4 (,, N/50)	31.77	65.99	1.50202	1.81948
5 (,, N/25)	82.61	108.02	1.91703	2.03350
6 (,, N/10)	277.88	208.48	2.44386	2.31907

By means of the method of least squares, the values of the two constants 1/n and k of FREUNDLICH's adsorption isotherms

$$x/m = k\,C^{1/n}$$

were calculated. According to the formula

$$\log k' = (\log k + 3 \times 1/n) - 3\ ,$$

the values of k' was calculated from the value of k, the latter being the constant when the calculation was carried out on the basis of mg and k' the constant which was calculated on the basis of g.

TABLE 33.

Values of the constants of FREUNDLICH's adsorption isotherms.

Starch	The concentrations of iodine used were					
	Low			High		
	$1/n$	k	k'	$1/n$	k	k'
Potato (Kojima)	0.25111	23.176	0.15967	0.60085	13.336	0.42423
Dog-tooth violet	0.25695	26.705	0.15756	0.54344	10.536	0.44976
Wheat (Kojima)	0.29195	23.268	0.17482	0.53400	10.375	0.41495
Sorghum	0.56990	10.896	0.55843	0.40015	26.981	0.43805
Rice	0.35926	20.983	0.25100	0.41410	20.302	0.35470
Italian millet	0.27408	33.320	0.22128	0.40818	44.107	0.40429
Barley	0.26451	36.099	0.24441	1.36818	0.421	5.3547
Corn (Kingsford)	0.27545	25.675	0.17213	0.50851	11.577	0.38824

The values of the constants 1/n, k and k' were different when the concentrations of the solutions of iodine were different as has already been reported in the author's former investigation upon the starch of barley. The value of 1/n was lower, the value of k was higher and the value of k' was lower in the case of the low concentration of iodine than in the case of the high concentration. When the concentration of iodine was low, the values of 1/n, k and k' were smaller in the case of the starches of the tuber plants than in the case of the cereal plant starches and when the concentration of iodine was high the relation was the opposite.

For the purpose of examining the correlations between 1/n, *k* and *k'*, the author calculated the coefficients of correlation between 1/n and *k*, 1/n and *k'* as shown in the following table.

TABLE 34.

Coefficients of correlation between 1/n and *k*, 1/n and *k'*.

	The concentrations of iodine used were	
	Low	High
Between 1/*n* and *k*.	−0.8556	−0.9753
Between 1/*n* and *k'*.	0.9619	0.4260

In the calculation of the values when the concentrations of iodine used were high, the values for the barley starch were not used which were exceptionally different from the other values. From the results of Table 34, it is seen that there are close correlations between 1/n and *k*, 1/n and *k'* when the concentrations of iodine used were low. Between 1/n and *k*, a negative correlation was observed, but the coefficient of correlation between 1/n and *k'* was 0.4260 and the correlation was not sufficient when the concentration of iodine used were high.

The starch was treated with sufficient quantities of the solution of *iodine potassium iodide*. The jod-starch formed was separated from the solution by means of a centrifugal machine. The separated jod-starch was washed repeatedly with the solution of 1% potassium iodide until the washing was completely colorless. The substance was washed well with water and dried in a desiccator of diminished pressure containing phosphoric anhydride. The jod-starch was treated with potassium hydroxide and potassium permanganate, where the free iodine was oxidized to iodate. The solution was acidified by the addition of hydrochloric acid; to the solution was added potassium iodide solution and the solution was titrated with the solution of natrium thiosulphate. The content of iodine measured by the described treatment was as follows.

TABLE 35.

Iodine content of the jod-starch.

Starch	Quantities of iodine (g)	k'
Potato (Kojima)	0.01558	0.15967
Dog-tooth violet	0.01589	0.15756
Wheat (Kojima)	0.01273	0.17482
Sorghum	0.00468	0.55843
Rice	0.01548	0.25100
Italian millet	0.02118	0.22128
Barley	0.02361	0.24441
Corn (Kingsford)	0.01915	0.17213

The values of k' in the table were the values of the constants k' of the adsorption of iodine when the concentration of iodine used were low. The quantities of iodine measured were greatest in the starch of barley and diminished in the order the starches of Italian millet, corn, dog-tooth violet, potato, rice, wheat and sorghum. It could be seen that the quantities of iodine measured were about 1/10 of the values of k' when they were compared as shown in Table 35. In other words, definite quantities of iodine counting to about 1/10 of the constants k' were combined with the starch in a form that was not removed by the washing with the potassium iodide solution. The mode of the combination between the starch and the iodine was supposed to be either the formation of a solid solution or a chemical combination between them.

Chapter II

Electrodialysis of the Starches

The action of electric current upon the starch was studied from many decades ago. BRESTER (19) stated that the starch was not changed by the electric current, that the reaction was neutral, and that the sugar was not formed by the treatment continued for 5 days. ROSENTHAL (79) and HEIMROD (37) recognised that electromagnetic force decomposes starch just like an enzyme does, and NEUBERG (62)

reported that the starch was scarcely effected by the action of 220 volts of direct current, and after 4–5 days there was formed a very slight amount of reducing sugar. LOEB (52), and LOEB and SATO (53) reported that an induction current decomposes starch and forms rapidly reducing substance.

On the dialysis of starch solution, BECKMANN (5), MÜLLER (60), BERCZLLER (7), SAMEC and HAERDTL (89), SAMEC and MAYER (93), *HOLMBER (39), SAMEC and BLINC (88) have published* reports. It was recognized that the dextrin did not pass the membrane.

Thus, on the effect of electric current upon the starch, the reported results vary widely amongst these authors; some reported that the starch was not decomposed but others reported that it was decomposed to form the reducing substance. Therefore, the present author attempted to ascertain clearly how the electric current effects the starch particle, and then to discover the difference between the original starch particle and the starch particle which was effected by the electric current. Accordingly the following experiments were carried out by him.

§ 1. Method

The electro-dialysis of starch particle was carried out with PAULI's electro-dialysator. For the dialysis membrane, the sulphuric paper of the best quality was used. Ten g of starch were suspended in water and put into the middle cell of the dialysator. Then, 110 volts direct current was passed through; every two hours the water in both sides of the dialysator was changed. At first the strength of current passed was 5–6 milliamperes, but by and by the ampherage was increased and at last is reached the maximum of 12 milliamperes, then again it decreased, and after 8 hours' electro-dialysis the current decreased to 5–6 milliamperes. Therefore, this time was considered as the end point of the experiment. The water in both sides of the dialysator and the solution in the middle cell which was separated from the starch were evaporated till they became 100 c.c. respectively. With 25 c.c. of these solutions respectively and also with 25 c.c. of these solutions respectively which had been boiled for 1 minute after the addition of 2 c.c. of concentrated hydrochloric acid, the reducing substances which reduced FEHLING's solution by BERTLANDT's method were measured. These results were taken as the amount of potassium permanganate solution titrated.

TABLE 36.

Amount of reducing substance formed by electro-dialysis.
c.c. of $KMnO_4$ titrated for 10 g of starch.

Starch	Hydrolysed by conc. HCl					
	Before			After		
	Anode	Cathode	Middle	Anode	Cathode	Middle
Potato (Kojima)	1.80	4.40	1.60	3.60	3.60	5.80
Dog-tooth violet	0.80	0.60	0.60	1.80	2.20	2.20
Wheat (Kojima)	0.80	0.48	1.80	1.60	1.20	6.40
Sorghum	0.60	1.00	1.00	2.00	1 60	2.40
Rice	0.40	0.80	0.60	1.60	1.80	3.00
Italian millet	0.40	0.40	0.40	2.00	1.60	2.00
Barley	1.00	0.80	0.80	2.00	2.00	3.00
Corn (Kingsford)	0.60	0.40	1.20	1.60	1.60	2.40

The effect of the electric current was to separate the reducing substance from the starch also substance which showed reducing power after hydrolysis by acid. It was not distinctly determined, however, in which part of the dialysator this substance was abundant, but it was separated from both sides. The amount of this substance in the middle cell was the greatest, which suggests that from the starch had separated mostly a particle of such size that it could not pass through the dialysis membrane.

From the starch also was separated large amounts of the substance which showed the reducing power after hydrolysis by acid. This substance was of two kinds, the one consisted of too great particles to pass through the membrane, but the other of so little particles that it could pass through the membrane.

From these results, it was observed that the electric current had decomposed the starch though the degree of decomposition was slight. In this case from the starch were separated the reducing substance and the other substances which showed reducing power after hydrolysis by acid, both in particles of widely differing size, from great ones which could not pass through the membrane to little ones which could.

The phosphorus content of the same solution which was used for the measurement of the reducing substance was measured by BELL-DOISY's colorimetric method modified by BRIGGS. But the phosphorus was not obtained in the solution from the anode, but only in the *solution from the cathode was the phosphorus content measured as* follows:—

TABLE 37.

Phosphorus content of the solution from the cathode after electro-dialysis.

Starch	mg for 1 g of starch	% for phosphorus content of original starch
Potato (Kojima)	0.0492	9.23
Dog-tooth violet	0.0397	15.92
Wheat (Kojima)	0.1016	17.32
Sorghum	0.0421	19.72
Rice	0.0594	26.67
Italian millet	0.0748	38.00
Barley	0.0516	20.44
Corn (Kingsford)	0.0603	29.00

Phosphorus had migrated to the cathode by the electro-dialysis of starch, and in this case the phosphorus seemed to be charged as cation but not as anion such as PO_4''' ion. It must be a complex organic compound of phosphorus and was charged as cation by electro-dialysis. But this organic compound of phosphorus seemed to have not the least reducing power, because it was observed that the amounts of reducing substances which were separated in both sides of the dialysator were about the same and that there was no quantitative relation between the reducing substance and the substance containing the phosphorus.

§ 2. Water, phosphorus and nitrogen content of electro-dialysed starch

The water, phosphorus and nitrogen content of starch separated by electro-dialysis as described above were measured respectively.

TABLE 38.

Water, phosphorus and nitrogen content of electro-dialysed starch.

Starch	Water (%)	Nitrogen (% for dry subs.)	Phosphorus (mg in 1 g of starch)
Potato (Kojima)	13.81	0.0137	0.4226
Dog-tooth violet	14.80	0.0389	0.1970
Wheat (Kojima)	16.69	0.0129	0.4325
Sorghum	15.11	0.0188	0.1450
Rice	13.93	0.0145	0.1400
Italian millet	14.91	0.0312	0.1525
Barley	14.64	0.0147	0.1880
Corn (Kingsford)	14.69	0.0221	0.1643

To ascertain how much the phosphorus and nitrogen content of starch was decreased or increased after electro-dialysis, the phosphorus and nitrogen content of the original starch was taken as 100 and the ratios of the above values were calculated as follows.

TABLE 39.

Phosphorus and nitrogen content of starch before and after electro-dialysis.

Starch	Original starch (%)	Electro-dialysed starch (%)	%
	Nitrogen		
Potato (Kojima)	0.0198	0.0137	69.18
Dog-tooth violet	0.0481	0.0389	80.87
Wheat (Kojima)	0.0176	0.0129	73.30
Sorghum	0.0254	0.0188	74.03
Rice	0.0184	0.0145	78.81
Italian millet	0.0332	0.0312	93.99
Barley	0.0169	0.0147	86.98
Corn (Kingsford)	0.0227	0.0221	97.36

TABLE 39. *(Continued)*

Starch	Original starch (%)	Electro-dialysed starch (%)	%
	Phosphorus		
Potato (Kojima)	0.5333	0.4226	79.25
Dog-tooth violet	0.2495	0.1970	78.96
Wheat (Kojima)	0.5865	0.4325	73.74
Sorghum	0.2131	0.1450	68.05
Rice	0.2228	0.1400	62.84
Italian millet	0.1968	0.1525	77.47
Barley	0.2524	0.1880	74.49
Corn (Kingsford)	0.2078	0.1643	79.05

The phosphorus and nitrogen content of starch were both decreased by electro-dialysis. The degree of decrease was 70% to 97% of the content of the original starch in the case of nitrogen. In the case of phosphorus it was 62% to 80%. Thus it was observed that the degree of decrease of phosphorus was greater than that of nitrogen.

The phosphorus content of the solution which was obtained from the polar cell by the dialysis as described above was compared with the amount of phosphorus lost from the original starch.

TABLE 40.

Phosphorus content of the solution obtained from the polar cell by dialysis and the amount of phosphorus of starch lost by dialysis.

(% of the content of original starch)

Starch	In the polar solution	Lost by dialysis	Starch	In the polar solution	Lost by dialysis
Potato (Kojima)	9.23	20.75	Rice	26.67	37.16
Dog-tooth violet	15.92	21.04	Italian millet	38.00	22.53
Wheat (Kojima)	17.32	26.26	Barley	20.44	25.51
Sorghum	19.72	31.95	Corn (Kingsford)	29.00	20.95

According to this table, except in the case of corn and Italian millet starch, the phosphorus amount contained in the polar solution was smaller than that lost by dialysis. This suggested that the phosphorus contained in the polar solution had originated from the starch used. This agrees well with SAMEC's statement that the electro-dialysis of starch frees the phosphorus contained in starch.

From these results, that the phosphorus and nitrogen content of starch were decreased and the existence of phosphorus and reducing substance in the solution used for dialysis were observed as a result of electro-dialysis, it may be said that the starch particle is changed in its construction in some way as a result of electro-dialysis. This agrees well with ROSENTHAL's, NEUBERG's and LOEB's reports.

§ 3. Acetylation of the electro-dialysed starch

By the same method as described before, the acetylation was carried out by the use of pyridin and acetic acid anhydride at room temperature. The acetyl content of the product was measured with the following results.

TABLE 41.

Acetyl content of electro-dialysed and acetylated starch.

Starch	Acetyl group (%)
Potato (Kojima)	48.43
Dog-tooth violet	48.96
Wheat (Kojima)	48.43
Sorghum	47.39
Italian millet	46.86
Barley	52.64
Corn (Kingsford)	43 17

The elementary composition of the products was determined by the micro method of elementary analysis with the following resultes.

TABLE 42.

Elementary analysis of the acetyl electro-dialysed starches.

Starch	Sample (mg)	H_2O (mg)	CO_2 (mg)	H (%)	C (%)
Potato (Kojima)	4.555	2.945	7.980	6.987	47.77
	4.165	2.651	7.270	7.119	47.60
				7.05	47.68
Dog-tooth violet	5.090	3.130	8.810	6.879	47.21
	5.020	3.045	8.740	6.785	47.47
				6.83	47.34
Wheat (Kojima)	6.045	3.735	10.695	6.911	48.25
	4.350	2.715	7.750	6.982	48.59
				6.95	48.42
Sorghum	6.230	3.730	10.755	6.697	47.09
	4.620	2.675	7.950	6.477	46.93
				6.59	47.01
Italian millet	4.350	2.915	7.770	7.496	48.71
	4.925	3.340	8.770	7.586	48.56
				7.54	48.63
Barley	5.170	3.270	9.150	7.074	48.26
	3.345	2.110	5.950	7.058	48.52
				7.07	48.39
Corn (Kingsford)	6.225	3.500	10.690	6.290	46.82
	5.395	2.925	9.230	6.064	46.66
				6.18	46.74

The results were arranged in the following table.

TABLE 43.

Elementary composition of acetylated electro-dialysed starches.

Starch	C	H	O
Potato (Kojima)	47.68	7.05	45.27
Dog-tooth violet	47.34	6.83	45.83
Wheat (Kojima)	48.42	6.95	44.63
Sorghum	47.01	6.59	46.40
Italian millet	48.63	7.54	43.83
Barley	48.39	7.07	44.54
Corn (Kingsford)	46.74	6.18	47.08

The electro-dialysed starch was acetylated more easily than the original starch. The starches of potato, wheat and dog-tooth violet which were not acetylated at the room temperature in the untreated state were acetylated when they were electro-dialysed. The content of the acetyl group of the acetylated electro-dialysed starches was higher than that of the original acetyl starches. While the latter measured 40.02–45.19%, the former measured 43.17–52.64%. Comparing the results with the theoretical content of the acetyl group of acetyl glucose, it was found that the ratios of the acetyl group to the glucose were 3.2–4, or generally 3.80–4.00. Therefore, the acetylated electro-dialysed starches are considered to be the mixture of 4–5 molecules of tetraacetyl glucose and 1 molecule of triacetyl glucose, or rather, to be tetraacetyl glucose. The starches of the tubers were changed so as to be more easily acetylated than those of the cereal plants and the content of the acetyl group was higher in the case of the tuber starches than of the cereal.

Thus electro-dialysis was considered to result in some kind of changes in the particles of the starches. The changes were considered to be the changes such as to make the particles of the starches easily reacted upon chemically. The electro-dialysis was further believed to decompose the starches very slightly.

§ 4. Electrical conductivity of the solutions of the electro-dialysed starches

By the same method as that described before, 2% solution of the electro-dialysed starch was prepared. The electrical conductivity of this solution was measured at 18°C. using a cell whose cell constant was 0.6096.

TABLE 44.

Electrical conductivity of the solutions of the electro-dialysed starches.

Starch	$K \cdot 10^5$	Starch	$K \cdot 10^5$
Potato (Kojima)	4.692	Rice	0.926
Dog-tooth violet	1.163	Italian millet	0.908
Wheat (Kojima)	4.100	Barley	0.784
Sorghum	1.187	Corn (Kingsford)	0.752

The electrical conductivity was at maximum in the potato electro-dialysed starch and decreased in the order of the starches of wheat, sorghum, dog-tooth violet, rice, Italian millet, barley and corn. The order was almost identical with that of the original starches. These values of the electro-dialysed starches were compared with those of the original starches as follows.

TABLE 45.

Electrical conductivity of the original and the electro-dialysed starches and the ratios between these values.

Starch	Original starch	Electro-dialysed starch	Ratio
Potato (Kojima)	$3.429 \cdot 10^{-5}$	$4.692 \cdot 10^{-5}$	100 : 136.9
Dog-tooth violet	2.988	1.163	38.92
Wheat (Kojima)	3.492	4.100	117.4
Sorghum	2.730	1.187	43.48
Rice	2.615	0.926	35.42
Italian millet	2.102	0.908	43.20
Barley	0.893	0.784	87.78
Corn (Kingsford)	1.159	0.752	64.88

The electrical conductivity of the solutions of the electro-dialysed starches had increased in the cases of the potato and the wheat starches whose values were respectively 136.9% and 117.4% of the original values. However, the values had decreased in the cases of the other starches whose values were 35–87% of the original values.

As shown above, the phosphorus and the nitrogen content of the starches decreased as a result of electro-dialysis and reducing substances were separated from the starches. Therefore, the starches had decreased to the extent of substances liberated when they were dissolved in solutions by the treatment of electro-dialysis. The fact that the electrical conductivity of the solution of the electro-dialysed starch showed a lower value than that of the original starch could be easily deduced. But the author could not find the reason why there should be increase of the electrical conductivity in the cases of the potato and the wheat starches.

§ 5. *Viscosity of the solutions of the electro-dialysed starches*

For the purpose of determining the viscosity of the solutions of the electro-dialysed starches and also the differences of those values compared with the original starches, the following determinations were carried out. The solution of the starch was prepared as described before heating the material under pressure in an autoclave. The viscosity was determined by the OSTWALD's viscosimeter at 20°C. The flowing time of water was taken as 1 and the relative viscosities of the solutions were calculated. At the same time, the specific values of the viscosities were calculated taking the viscosity of the solution of the original starch of the same concentration as 100.

TABLE 46.

Viscosity of the solutions of electro-dialysed and original starches and their ratios when the latter values were taken as 100.

Starch	0.5 %	1.0 %	2.0 %	4.0 %
	The electro-dialysed starches.			
Potato (Kojima)	1.091	1.163	1.273	1.923
Dog-tooth violet	1.345	1.818	2.218	5.654
Wheat (Kojima)	1.091	1.327	1.436	1.781
Sorghum	1.363	2.109	5.508	34.600
Rice	1.309	1.963	5.344	39.410
Italian millet	1.363	2.072	5.418	54.080
Barley	1.254	1.418	1.545	7.818
Corn (Kingsford)	1.291	1.781	2.581	21.820
	The original starches.			
Potato (Kojima)	1.054	1.236	2.218	6.363
Dog-tooth violet	1.127	1.400	2.509	7.000
Wheat (Kojima)	1.091	1.327	2.636	13.600
Sorghum	1.327	2.090	7.654	53.390
Rice	1.273	1.963	6.908	—
Italian millet	1.309	2.018	6.527	—
Barley	1.109	1.309	1.781	9.745
Corn (Kingsford)	1.181	1.545	3.545	26.080

TABLE 46. (*Continued*)

Starch	0.5 %	1.0 %	2.0 %	4.0 %
	The ratios of the two.			
Potato (Kojima)	103.61	94.08	57.40	30.22
Dog-tooth violet	*119.34*	*129.86*	*88.41*	*80.76*
Wheat (Kojima)	100.00	100.00	54.46	13.09
Sorghum	102.71	100.91	71.96	64.82
Rice	*102.83*	*100.00*	*77.36*	—
Italianm millet	104.12	102.67	83.01	—
Barley	113.07	108.33	86.76	80.23
Corn (Kingsford)	109.31	115.27	72.81	83.68

The ratio of the viscosities of the solutions of the electro-dialysed and the original starches varried with the changes of the concentrations of the solutions respectively. In the cases of the concentrations of 0.5% and 1.0% with the exception of the potato starch of 1.0% the ratios were always greater than 100.00 or in other words, the viscosities of the solutions were increased by the electro-dialysis over the corresponding values of the original starches. In the cases of the corn and the dog-tooth violet starches, the ratios of 1.0% solutions were higher than those of 0.5%, but in all other cases the reverse was true. When the concentrations of the solution were 2.0% and 4.0%, the viscosities of the electro-dialysed starches were always smaller than those of the original starches. The greater the concentration, the more the viscosities decreased. The viscosities of the 4.0% original starches of Italian millet and rice were so high that they were undetermined. The viscosity of these same solutions was so reduced by electro-dialysis as to become determinable.

§ 6. Gold value of the electro-dialysed starches

In the same way as previously described, the author determined the gold values of the electro-dialysed starches.

TABLE 47.

Gold values of the electro-dialysed starches.

Starch		Starch	
Potato (Kojima)	12	Rice	11
Dog-tooth violet	2—6	Italian millet	6—7
Wheat (Kojima)	7	Barley	4
Sorghum	13	Corn (Kingsford)	4

In this case, the author found that there were optimum limits of the quantity for the protection of the gold solution as was seen in the case of the original starches.

When the values were compared with those of the original starches, there were observed no marked differences. The same values were obtained for the starches of potato, barley and corn but for the wheat starch the value decreased from 8 of the original to 7 of the electro-dialysed. According to the findings it may be said that electro-dialysis does not change the gold value of the starch or in other words, electro-dialysis does not change the protective power of the starch at all.

Considering the facts that the electro-dialysis had decreased the phosphorus and the nitrogen content of the starch and had separated the reducing substances from the starch, yet the protective power of the starch did not change at all, it may be deduced that the protective power of the starch has no remarkable relation to the composition and quantity of the ash constituents.

§ 7. Adsorption of iodine by the electro-dialysed starch granules

Electro-dialysis separated phosphorus, nitrogen and reducing substances from the starch. Therefore, it seemed to be of great interest to know how the adsorption of iodine by such electro-dialysed starch granules was influenced. The adsorption was conducted by the same method as described before with the following results and the calculations of the constants $1/n$, k and k' were carried out.

TABLE 48.

Adsorption of iodine by the electro-dialysed starch granules.

	Iodine left C (mg)	Iodine adsorbed x (mg)	log C	log x
		Potato starch (Kojima)		
1 (About N/200)	0.37	22.11	$\bar{1}$.56820	1.34459
2 (,, N/100)	4.89	41.79	0.68931	1.62107
3 (,, N/75)	11.24	50.55	1.05077	1.70372
4 (,, N/50)	27.50	67.82	1.43933	1.83136
5 (,, N/25)	59.14	129.54	1.77188	2.11241
6 (,, N/10)	275.44	206.52	2.44002	2.11241
		Dog-tooth violet starch		
1 (About N/200)	0.86	21.62	$\bar{1}$.93450	1.33486
2 (,, N/100)	6.84	39.84	0.83506	1.60032
3 (,, N/75)	13.69	48.10	1.13640	1.68215
4 (,, N/50)	32.75	61.57	1.51521	1.78937
5 (,, N/25)	82.61	106.07	1.91703	2.02560
6 (,, N/10)	271.28	210.68	2.43342	2.32352
		Wheat starch (Kojima)		
1 (About N/200)	0.73	21.75	$\bar{1}$.86332	1.33746
2 (,, N/100)	5.87	40.81	0.76864	1.61077
3 (,, N/75)	11.49	50.30	1.06032	1.70157
4 (,, N/50)	28.35	66.97	1.45255	1.82588
5 (,, N/25)	64.77	123.91	1.81137	2.09310
6 (,, N/10)	278.86	203.10	2.44528	2.30771
		Sorghum starch		
1 (About N/200)	1.96	20.52	0.29226	1.30643
2 (,, N/100)	9.78	36.90	0.99034	1.56703
3 (,, N/75)	14.91	46.88	1.17348	1.67099
4 (,, N/50)	22 48	72.84	1.35180	1.86237
5 (,, N/25)	37.88	150.80	1.57841	2.17840
6 (,, N/10)	257.60	224.36	2.41095	2.35094
		Rice starch		
1 (About N/200)	0.49	21.99	$\bar{1}$.69020	1.34223
2 (,, N/100)	5.38	41.30	0.73078	1.61595
3 (,, N/75)	11.24	50.55	1.05077	1.70372
4 (,, N/50)	25.91	69.41	1.41347	1.84142
5 (,, N/25)	67.45	121.23	1.82898	2.08360
6 (,, N/10)	266.88	215.08	2.42632	2.33260
		Italian millet starch		
1 (About N/200)	0.49	21.99	$\bar{1}$.69020	1.34223
2 (,, N/100)	5.87	40.81	0.76864	1.61077
3 (,, N/75)	11.00	50.79	1.04139	1.70578
4 (,, N/50)	28.35	66.97	1.45255	1.82588
5 (,, N/25)	66.97	121.71	1.82588	2.08532
6 (,, N/10)	251.51	230.45	2.40095	2.36257

TABLE 48. (*Continued*)

	Iodine left C (mg)	Iodine adsorbed x (mg)	log C	log x
		Barley starch		
1 (About N/200)	0.24	22.24	$\bar{1}$.38021	1.34713
2 (,, N/100)	2.57	44.11	0.40993	1.64454
3 (,, N/75)	5.99	55.80	0.77743	1.74663
4 (,, N/50)	18.57	76.75	1.26881	1.88508
5 (,, N/25)	52.67	136.01	1.72156	2.13357
6 (,, N/10)	272.37	209.09	2.43595	2.32033
		Corn starch (Kingsford)		
1 (About N/200)	0.73	21.75	$\bar{1}$.86332	1.33746
2 (,, N/100)	6.35	40.33	0.80277	1.60563
3 (,, N/75)	12.22	49.57	1.08707	1.69522
4 (,, N/50)	31.53	63.79	1.49872	1.80475
5 (,, N/25)	86.27	102.41	1.93586	2.01034
6 (,, N/10)	275.26	206.70	2.43974	2.31534

TABLE 49.

Values of the constants of FREUNDLICH's adsorption isotherms.

Starch	Concentrations of iodine used					
	Low			High		
	$1/n$	k	k'	$1/n$	k	k'
Potato (Kojima)	0.26800	27.612	0.17583	0.45736	16.776	0.39515
Dog-tooth violet	0.30614	26.643	0.22100	0.58061	17.550	0.96852
Wheat (Kojima)	0.38164	21.301	0.29740	0.66629	6.420	0.64034
Sorghum	0.46936	14.235	0.36558	0.39262	27.012	0.40683
Rice	0.28300	26.406	0.18651	0.48017	15.085	0.42597
Italian millet	0.27264	27.825	0.18297	0.48395	14.967	0.42363
Barley	0.28499	33.497	0.23987	0.36290	28.615	0.35098
Corn (Kingsford)	0.28726	23.836	0.17338	0.54419	9.503	0.40880

From the results, the coefficients of correlation between $1/n$ and k and $1/n$ and k' were calculated.

TABLE 50.

Coefficients of correlation between 1/n and *k*, 1/n and *k'*.

	Concentrations of iodine used	
	Low	High
Between 1/*n* and *k*.	−0.8733	−0.6235
Between 1/*n* and *k'*.	0.9682	0.4847

When the concentrations of iodine used were low, there was a negative close relation between 1/n and *k*, or the greater the value of 1/n, the smaller was the value of *k*, and also there was a close positive relation between 1/n and *k'*, or the greater the value of 1/n, the greater was the value of *k'*. However, the coefficients of correlation were − 0.6235 and 0.4847, when the concentrations of iodine were high. The correlation in this case, was not so remarkable as in the other case.

§ 8. Mechanism of the hydrolysis of the electro-dialysed starches by the action of the diastase

Studies were made on the mechanism of the hydrolysis of electro-dialysed starch by the action of diastase by means of the method described before. One c.c. of potassium permanganate solution used in the study corresponded to 0.009707 g of copper. The following results were the means of 3–5 determinations.

TABLE 51.

Hydrolysis of electro-dialysed starches by the action of diastase.

Time (min.)	5	10	20	40	80	160	End
			Potato starch (Kojima)				
$KMnO_4$ (c.c.)	0.95	1.88	2.98	3.55	3.73	3.93	4.43
Cu (mg)	*9.2*	*18.2*	*28.9*	*34.4*	*36.2*	*38.1*	*43.0*
Maltose (mg)	5.6	13.1	22.0	26.6	28.0	29.7	33.8
%	16.57	42.01	65.08	78.70	82.84	87.87	100.00

TABLE 51. (*Continued*)

Time (min.)	5	10	20	40	80	160	End
Dog-tooth violet starch							
$KMnO_4$ (c.c.)	—	1.92	3.0	3.3	3.55	3.63	4.43
Cu (mg)	—	18.6	29.1	32.0	34.5	35.2	43.0
Maltose (mg)	—	13.4	22.2	24.6	26.6	27.3	33.8
%	—	39.64	65.68	72.78	78.70	80.77	100.00
Wheat starch (Kojima)							
$KMnO_4$ (c.c.)	1.62	2.37	2.97	3.67	4.05	4.30	4.55
Cu (mg)	15.7	23.0	28.8	35.6	39.3	41.7	44.2
Maltose (mg)	10.9	17.1	21.9	27.6	30.7	32.6	34.7
%	31.41	49.28	63.11	79.54	88.47	93.95	100.00
Sorghum starch							
$KMnO_4$ (c.c.)	1.15	1.98	2.83	3.13	3.38	3.52	4.13
Cu (mg)	11.2	19.2	27.5	30.4	32.8	34.2	40.1
Maltose (mg)	7.1	13.9	20.7	23.2	25.2	26.3	31.1
%	22.81	44.41	66.49	74.12	80.51	84.03	100.00
Rice starch							
$KMnO_4$ (c.c.)	1.15	2.25	3.22	3.52	3.65	3.80	4.50
Cu (mg)	11.2	21.8	31.2	34.2	35.4	36.9	43.7
Maltose (mg)	7.1	16.0	23.9	26.3	27.4	28.5	34.3
%	20.70	46.65	69.68	76.68	79.89	83.08	100.00
Italian millet starch							
$KMnO_4$ (c.c.)	—	0.73	2.12	3.07	3.25	3.5	4.43
Cu (mg)	—	7.1	20.6	29.8	31.5	34.0	43.0
Maltose (mg)	—	3.9	15.0	22.7	24.2	26.2	33.8
%	—	11.54	44.38	67.16	71.63	77.51	100.00
Barley starch							
$KMnO_4$ (c.c.)	—	1.67	2.5	3.05	3.45	3.5	4.0
Cu (mg)	—	16.2	24.3	29.6	33.5	34.0	38.8
Maltose (mg)	—	11.4	18.1	22.6	25.8	26 2	30.2
%	—	37.75	59.93	74.83	85.43	86.75	100.00
Corn starch (Kingsford)							
$KMnO_4$ (c.c.)	—	2.02	2.85	3.27	3.5	3.7	4.65
Cu (mg)	—	19.6	27.7	31.7	34.0	35.9	45.1
Maltose (mg)	—	14.2	20.9	24.3	26.2	27.9	35.5
%	—	40.00	58.87	68.45	73.80	78.59	100.00

The values of the two constants k and k' of the equation

$$\frac{1}{t^{k'}} \cdot \frac{x}{a(a-x)} = k$$

were calculated from the described results by the method of least squares.

TABLE 52.

Values of the two constants k and k'.

Starch	k	k'	Starch	k	k'
Potato (Kojima)	0.0007367	1.0042	Rice	0.001248	0.7950
Dog-tooth violet	0.002155	0.6304	Italian millet	0.0001888	1.1098
Wheat (Kojima)	0.0007749	1.0577	Barley	0.0009658	0.8849
Sorghum	0.001163	0.8118	Corn (Kingsford)	0.002094	0.5899

Introducing the values of the constants in the above equation, the percentages of maltose produced by hydrolysis were calculated and compared with those actually found as in the following table.

TABLE 53.

Percentages of maltose produced by hydrolysis.

Time (min.)	5	10	20	40	80	160
			Potato starch (Kojima)			
Observed	16.57	42.01	65.08	78.70	82.84	87.87
Calculated	27.05	42.71	59.87	74.96	85.73	92.33
Difference	−10.48	−0.70	5.21	3.74	−2.89	−4.46
			Dog-tooth violet starch			
Observed	—	39.64	65.68	72.78	78.70	80.77
Calculated	—	47.92	58.74	68.12	77.34	84.08
Difference	—	−8.28	6.94	4.66	1.36	−3.31

TABLE 53. (*Continued*)

Time (min.)	5	10	20	40	80	160
			Wheat starch (*Kojima*)			
Observed	31.41	49.28	63.11	79.54	88.47	93.95
Calculated	29.83	46.95	64.81	79.31	88.86	94.32
Difference	1.58	2.33	−1.70	0.23	−0.39	−0.37
			Sorghum starch			
Observed	22.81	44.41	66.49	74.12	80.51	84.03
Calculated	29.09	43.00	56.95	69.92	80.31	87.74
Difference	−6.28	1.41	9.54	4.20	0.20	−3.71
			Rice starch			
Observed	20.70	46.65	69.68	76.68	79.89	83.08
Calculated	30.98	43.78	57.47	70.10	82.02	87.57
Difference	−10.28	2.87	12.21	6.58	−2.13	−4.49
			Italian millet starch			
Observed	—	11.54	44.38	67.16	71.63	77.51
Calculated	—	19.55	34.41	53.10	70.96	84.06
Difference	—	−8.01	9.97	14.06	0.67	−6.55
			Barley starch			
Observed	—	37.75	59.93	74.83	85.43	86.75
Calculated	—	42.52	57.77	71.65	82.35	89.60
Difference	—	−4.77	2.16	3.18	3.08	−2.85
			Corn starch (Kingsford)			
Observed	—	40.00	57.87	68.45	73.80	78.59
Calculated	—	44.89	55.10	64.86	73.52	80.70
Difference	—	−4.89	2.77	3.59	0.28	−2 11

The calculated and the observed values nearly coincide, therefore, it follows that the adopted equation expresses the mechanism of the hydrolysis of the electro-dialysed starch by the action of diastase.

The values of k were 0.0007–0.0021 and were greater than the values 0.0006–0.0013 of the original starches as stated in a former paragraph. The starch was changed into a more easily hydrolysable

form by the treatment of the electro-dialysis. The value of k of the Italian millet electro-dialysed starch was 0.000189 and was markedly small if compared with the other values. This fact has already been seen in the case of the original Italian millet starch as described before. However, the latter value was 0.000096 which was smaller than the value of the present investigation. Generally speaking, *the starch had undergone some kind of changes upon the molecular* structure by electro-dialysis and had changed into a form that was easily hydrolysed by the action of diastase.

To find the relation between k and k', the author had carried out the same calculation as previously described with the exception of the special case of the Italian millet starch.

Observation equations.

$$-3.1327 = 1.0042\,a+b \quad \text{or} \quad b+1.0042\,a+3.1327 = 0$$
$$-3.1108 = 1.0577\,a+b \qquad b+1.0577\,a+3.1108 = 0$$
$$-3.0151 = 0.8849\,a+b \qquad b+0.8849\,a+3.0151 = 0$$
$$-2.6789 = 0.5899\,a+b \qquad b+0.5899\,a+2.6789 = 0$$
$$-2.6665 = 0.6304\,a+b \qquad b+0.6304\,a+2.6665 = 0$$
$$-2.9036 = 0.7950\,a+b \qquad b+0.7950\,a+2.9036 = 0$$
$$-2.9343 = 0.8118\,a+b \qquad b+0.8118\,a+2.9343 = 0$$

Normal equations

$$7\,b+5.7739\,a+20.4414 = 0$$
$$5.7739\,b+4.9465\,a+17.0559 = 0$$

Solving
$$a = -1.0599$$
$$b = -2.0459$$

Therefore,
$$\log k = -1.0599\,k'-2.0459.$$

Thus the author is able to say that the same deduction is substantiated from this calculation as in the former calculation or in other words that the relation between *log* k and k' can be expressed by an equation of a straight line.

When the values of the two constants k and k' of the original and the electro-dialysed starches are compared, it is observed that the values of k are always markedly increased by the electro-dialysis

of the starch but the values of k' are decreased. It is concluded therefore, that the starch is changed into a more easily hydrolysed form by the action of electric current or in other words that the electro-dialysis somehow decomposes the starch molecule changing it to a more unstable form than the original starch in respect to the action of diastase.

Chapter III.

Oxidation of the Starches

The fact that when starch is treated with the oxidizing agents, soluble starch, dextrine and glucose are principally produced and that many other compounds—namely many acids and furfurals are also produced, has been reported by many investigators (112). The oxidizing agents used in these cases were very numerous viz., hydrogen peroxide, natrium bicarbonate, chlorine or chlorous acid, bleaching powder, manganese oxide, natrium peroxide, ferric chloride, calcium permanganate, hydrochloric acid and potassium bichromate, activin (natrium salt of *p*-toluensulfochloramide) and iron.

When M. SAMEC (86) treated the starch with natrium peroxide, hydrogen peroxide, ammonium persulfate, potassium permanganate, natrium perborate and air oxygen, he obtained the oxidized products of the starch. He compared many properties of these different products.

The present author intending to investigate the properties and the differences of the products of many sorts of starches carried out the following examinations.

§ 1. Method of oxidation and phosphorus content of oxidized starches

Use was made of three kinds of oxidizing agents; viz., potassium permanganate, natrium perborate and ammonium persulphate.

To 20 g of starch were added 52 c.c. of 2% potassium permanganate solution and 52 c.c. of water, then the preparate was stood for 2 hours at room temperature, while the oxidation of starch proceeded. The solution was made acid by the addition of sulphuric acid; to the

solution was added very carefully and slowly a small amount of natrium thiosulphate finally the colour of solution disappeared, then the starch was separated, washed thoroughly with water, and dried at room temperature. This was called sample No. 1 of the oxidized starch.

To 10 g of starch were added 100 c.c. of water and then 4 g of natrium perborate; the mixture was stood for 4 days at room temperature, while the oxidation of starch proceeded. Then the starch was separated, washed carefully with water, and dried at room temperature. Thus sample No. 2 was obtained.

To 10 g of starch were added 100 c.c. of water and 5 g of ammonium persulphate; the whole was stood for 10 hours at room temperature, while the oxidation of starch proceeded. Then the starch was separated, washed carefully with water, and dried at room temperature. Sample No. 3 was thus obtained.

These samples were white powders and there was no difference in appearance between these samples and the original starches.

The water content of the oxidized starch was measured with the results as follows.

TABLE 54.

Water content of the oxidized starch.

Starch	Sample No. 1	Sample No. 2	Sample No. 3
Potato (Kojima)	11.39	17.30	11.31
Dog-tooth violet	9.47	11.51	12.48
Wheat (Kojima)	11.63	16.82	19.26
Sorghum	9.60	13.76	16.78
Rice	9.72	12.99	16.14
Italian millet	9.66	13.32	11.94
Barley	9.18	13.03	12.60
Corn (Kingsford)	9.78	11.82	12.03

These samples were ashed by NEUMANN's ashing method and the excess of acid was neutralized by natrium hydroxide solution. Then the phosphorus content of these solutions was measured by BELL-DOISY's method modified by BRIGGS, and the values were compared with those of phosphorus content of the original non-oxidized starch taken as 100.

TABLE 55.

Phosphorus content of the oxidized starch.

Starch	Sample No. 1		Sample No. 2		Sample No. 3	
	H_2O free %	% of P-content of original starch	H_2O free %	% of P-content of original starch	H_2O free %	% of P-content of original starch
Potato (Kojima)	0.054	100.8	0.046	87.08	0.051	96.45
Dog-tooth violet	0.023	93.87	0.025	98.70	0.022	88.39
Wheat (Kojima)	0.055	93.28	0.044	75.02	0.051	86.38
Sorghum	0.017	79.39	0.015	69.07	0.019	90.80
Rice	0.021	91.96	0.014	63.97	0.017	74.94
Italian millet	0.019	96.74	0.015	76.19	0.016	79.03
Barley	0.019	74.16	0.020	79.73	0.017	67.10
Corn (Kingsford)	0.016	79.45	0.018	87.86	0.016	76.03

According to this table, the phosphorus content of all these samples, except sample No. 1 of potato starch, was decreased by the action of the oxidizing agents. In general, sample No. 2, which was the starch oxidized by natrium perborate, had decreased most markedly in the phosphorus content; sample No. 3 which was oxidized by ammonium persulphate was next, and the effect of potassium permanganate upon the phosphorus content of the oxidized starch was the least pronounced.

Observing this result from the standpoint of the sorts of plants from which the starch was got, the phosphorus content of the starch of the tubers, such as potato and dog-tooth violet, showed the smaller decrease by oxidation than that of the starch of the cereal plants. Therefore, also in this case, the starch may properly classified in two kinds; the one is the starch of tubers, and the other is of cereal plants.

§ 2. Acetylation of the oxidized starches

The oxidized starch was acetylated at room temperature by pyridin and acetic acid anhydride. The method was the same as described before. In general, the reaction was very slow, and there were some starches which were not acetylated though they were

stood for as long time as six months. The content of acetyl group of the starch which was fully acetylated was measured by the method described before.

TABLE 56.

Content of acetyl group of the acetyl oxidized starches.

Starch	Sample No. 1	Sample No. 2	Sample No. 3
Potate (Kojima)	—	40.41	—
Dog-tooth violet	49.49	55.81	—
Wheat (Kojima)	24.22	50.54	—
Sorghum	48.96	47.90	—
Rice	—	48.43	—
Italian millet	52.54	—	50.00
Barley	46.33	50.54	46.86
Corn (Kingsford)	50.54	47.39	—

In general, sample No. 2 was easily acetylated but sample No. 3 was acetylated with difficulty. The acetyl group content was mostly 46–52% excepting sample No. 1 of wheat starch. It seemed that the oxidized starch was acetylated more easily than the original starch, if they were treated by the same method, and also the number of kinds of starch which were acetylated was increased.

The acetyl group content was approximately 50%, and according to Table 10, it seemed that 1 glucose residue containing 4 acetyl groups, or the aggregate of tetraacetyl glucose.

§ 3. Viscosity of the solution of the oxidized starches

The oxidizing agent decreased the phosphorus content of starch, and made the starch easy to be acetylated, therefore, the author attempted to ascertain the viscosity of the solution of such oxidized starches. For this purpose, 0.5, 1.0, 2.0 and 4.0% starch solutions of every kind were prepared heating for 1 hour under a pressure of 1.3 kg per sq. cm., and the viscosity of those solutions was measured by OSTWALD's viscosimeter at 20°C. The numbers of the following table were calculated on the basis of the time of flow of water as 1.

TABLE 57.

Viscosity of the solution of oxidized starch.

Starch	0.5%	1.0%	2.0%	4.0%
Sample No. 1				
Potato (Kojima)	1.114	1.122	1.213	1.633
Dog-tooth violet	1.065	1.119	1.273	1.707
Wheat (Kojima)	1.096	1.122	1.247	1.598
Sorghum	1.037	1.059	1.081	1.241
Rice	1.037	1.041	1.052	1.192
Italian millet	1.041	1.041	1.104	1.289
Barley	1.044	1.037	1.080	1.207
Corn (Kingsford)	1.041	1.044	1.102	1.269
Sample No. 2				
Potato (Kojima)	1.086	1.231	1.415	2.092
Dog-tooth violet	1.120	1.404	2.063	5.944
Wheat (Kojima)	1.046	1.111	1.484	3.092
Sorghum	1.099	1.263	1.772	3.815
Rice	1.122	1.355	1.957	4.574
Italian millet	1.160	1.481	2.517	9.276
Barley	1.052	1.191	1.484	3.092
Corn (Kingsford)	1.054	1.185	1.479	2.685
Sample No. 3				
Potato (Kojima)	1.164	1.369	1.891	4.222
Dog-tooth violet	1.261	1.707	2.596	13.11
Wheat (Kojima)	1.185	1.354	1.750	3.111
Sorghum	1 189	1.420	1.894	3.092
Rice	1.092	1.176	1.442	2.259
Italian millet	1.089	1.231	1.550	2.741
Barley	1.115	—	1.690	3.667
Corn (Kingsford)	1.189	1.420	1.894	3.092

These numbers were calculated respectively on the basis of 100 for the viscosities of the original starch solutions of the same concentrations prepared under the same conditions.

TABLE 58.

Ratio of the viscosity of the solution of the oxidized starch to that of the original starch expressed in percent.

Starch	0.5%	1.0%	2.0%	4.0%
		Sample No. 1		
Potato (Kojima)	74.27	40.80	14.30	3.59
Dog-tooth violet	76.90	53.86	19.58	—
Wheat (Kojima)	69.50	39.96	16.42	3.95
Sorghum	78.15	50.67	14.12	2.33
Rice	81.46	53.03	15.23	—
Italian millet	79.53	51.59	18.45	—
Barley	94.15	79.22	60.64	12 39
Corn (Kingsford)	88.15	67.51	31.09	4.87
		Sample No. 2		
Potato (Kojima)	72.40	44.76	16.69	4.57
Dog-tooth violet	80.85	67.57	31.74	—
Wheat (Kojima)	66.31	39.57	17.55	4.62
Sorghum	82.82	60.43	25.15	7.15
Rice	88.15	69.03	29.81	—
Italian millet	88.62	73.39	38.56	—
Barley	94.86	90.99	83.39	31.74
Corn (Kingsford)	89.25	76.70	44.82	10.30
		Sample No. 3		
Potato (Kojima)	77.61	49.78	22.30	9.27
Dog-tooth violet	91.01	82.15	39.94	—
Wheat (Kojima)	75.15	46.05	23.03	7.69
Sorghum	89.62	67.95	24.75	5.79
Rice	85.78	59.91	20.87	—
Italian millet	83.24	60.99	23.74	—
Barley	100.6	—	94.91	37.62
Corn (Kingsford)	92.98	79.68	44.88	11.14

The viscosity of the solution of the starch was decreased by the action of the oxidizing agent. This phenomena is connected closely with the decrease in the phosphorus content. According to M. SAMEC the oxidizing agent separated the phosphorus from the starch and the existence of phosphorus caused the viscosity of the starch solution. Therefore, the starch which was treated by the oxidizing agent seemed to be very changed in the part where phosphorus is contained, i.e. in SAMEC's amylopectin.

Among the starches examined the viscosity of the solution of barley starch was always decreased least by oxidation, but that of wheat starch was the greatest. By the solution of oxidized starch of the same kind, the decreasing of the viscosity became by and by greater than in the case of original starch solution as the concentration of the solution became higher. This showed that the starch had decreased in the degree of aggregation as a result of the action of the oxidizing agent. Therefore, it seems that the constitution of the molecule is changed to a very simple form, and that the starch molecule was decomposed very much at the same time by the oxidizing agent.

§ 4. Adsorption of iodine by the oxidized starch granules

It has been observed in the above paragraphs that the starch is changed in respect to degree of aggregation of its molecule by oxidation, that the phosphorus content decreases and that its chemical construction is changed. Then, the author, intending to know how much change there is in the ability of adsorption of iodine by oxidized starch, treated the oxidized starch as described before. To 0.5 g of oxidized starch were added respectively 20 c.c. portions of about N/10, N/25, N/50, N/75, N/100 and N/200 iodine potassium iodide solution; the mixture was shaken for 30 minutes and stood for 30 minutes; then the oxidized starch was separated by a centrifugal machine, and the iodine content in 10 c.c. of the supernatant solution was measured by titration method. These numbers were calculated as the equivalents of 1 g of oxidized starch.

TABLE 59.

Amount of iodine adsorbed by oxidized starch.

	Iodine left C (mg)	Iodine adsorbed x (mg)	log C	log x
		Sample No. 1		
		Potato starch (Kojima)		
1 (About N/200)	0.73	25.13	$\bar{1}.86322$	1.40019
2 (,, N/100)	6.34	44.16	0.80209	1.64503
3 (,, N/75)	13.66	54.17	1.13545	1.73376
4 (,, N/50)	28.79	72.71	1.45924	1.86159
5 (,, N/25)	62.95	142.89	1.79900	2.15500
6 (,, N/10)	—	—	—	—
		Dog-tooth violet starch		
1 (About N/200)	0.49	23.91	$\bar{1}.69020$	1.37858
2 (,, N/100)	5.37	42.94	0.72997	1.63286
3 (,, N/75)	12.69	51.73	1.10346	1.71374
4 (,, N/50)	30.74	64.90	1.48770	1.81224
5 (,, N/25)	92.60	101.63	1.96661	2.00702
6 (,, N/10)	274.74	206.42	2.43892	2.31475
		Wheat starch (Kojima)		
1 (About N/200)	0.73	23.67	$\bar{1}.86332$	1.37420
2 (,, N/100)	5.73	42.58	0.75815	1.62921
3 (,, N/75)	12.69	51.73	1.10346	1.71374
4 (,, N/50)	26.84	68.81	1.42878	1.83765
5 (,, N/25)	62.00	132.25	1.79239	2.12139
6 (,, N/10)	279.26	201.91	2.44601	2.30516
		Sorghum starch		
1 (About N/200)	3.90	21.96	0.59106	1.34163
2 (,, N/100)	12.20	38.31	1.08636	1.58331
3 (,, N/75)	18.54	49.29	1.26811	1.69276
4 (,, N/50)	27.21	74.30	1.43473	1.88326
5 (,, N/25)	68.32	137.52	1.83455	2.13836
6 (,, N/10)	325.50	201.06	2.51255	2.30333
		Rice starch		
1 (About N/200)	1.22	24.64	0.08636	1.39164
2 (,, N/100)	7.81	42.70	0.89265	1.63043
3 (,, N/75)	14.15	53.68	1.15076	1.72981
4 (,, N/50)	27.33	74.18	1.43664	1.87029
5 (,, N/25)	70.76	135.08	1.84979	2.13059
6 (,, N/10)	320.64	196.91	2.51804	2.29427
		Italian millet starch		
1 (About N/200)	0.49	25.38	$\bar{1}.69020$	1.40449
2 (,, N/100)	4.27	46.24	0.63043	1.66502
3 (,, N/75)	6.25	61.58	0.79588	1.78944
4 (,, N/50)	24.62	76.86	1.39129	1.88570
5 (,, N/25)	59.90	145.94	1.77743	2.16418
6 (,, N/10)	307.93	218.62	2.48845	2.33975

TABLE 59. (*Continued*)

	Iodine left C (mg)	Iodine adsorbed x (mg)	log C	log x
		Barley starch		
1 (About N/200)	0.49	23.91	$\bar{1}$.69020	1.37858
2 (,, N/100)	3.68	44.63	0.56585	1.64963
3 (,, N/75)	8.30	56.12	0.91908	1.74912
4 (,, N/50)	20.01	75.64	1.30125	1.87875
5 (,, N/25)	53.19	141.03	1.72583	2.14931
6 (,, N/10)	282.80	198.37	2.45148	2.29747
		Corn starch (Kingsford)		
1 (About N/200)	0.49	23.91	$\bar{1}$.69020	1.37858
2 (,, N/100)	4.27	44.04	0.63043	1.64385
3 (,, N/75)	10.37	54.05	1.01578	1.73280
4 (,, N/50)	27.21	68.44	1.43473	1.83531
5 (,, N/25)	88.33	105.90	1.94611	2.02490
6 (,, N/10)	285.48	195.69	2.45557	2.29157
		Sample No. 2		
		Potato starch (Kojima)		
1 (About N/200)	1.10	24.77	0.04139	1.39393
2 (,, N/100)	8.91	41.60	0.94988	1.61909
3 (,, N/75)	17.08	50.75	1.23249	1.70544
4 (,, N/50)	38.80	62.71	1.58883	1.79734
5 (,, N/25)	90.04	115.80	1.95444	2.06371
6 (,, N/10)	323.06	203.50	2.50928	2.30856
		Dog-tooth violet starch		
1 (About N/200)	0.49	25.38	$\bar{1}$.69020	1.40449
2 (,, N/100)	5.12	45.38	0.70927	1.65686
3 (,, N/75)	13.18	54.66	1.11992	1.73767
4 (,, N/50)	34.65	66.86	1.53970	1.82517
5 (,, N/25)	108.34	97.50	2.03479	1.98900
6 (,, N/10)	318.18	208.38	2.50267	2.31886
		Wheat starch (Kojima)		
1 (About N/200)	0.98	24.89	$\bar{1}$.99123	1.39602
2 (,, N/100)	9.03	41.48	0.95569	1.61784
3 (,, N/75)	17.93	49.90	1.25358	1.69810
4 (,, N/50)	37.58	63.93	1.57496	1.80570
5 (,, N/25)	81.25	124.59	1.90982	2.09548
6 (,, N/10)	316.56	210.00	2.50045	2.32222
		Sorghum starch		
1 (About N/200)	2.93	22.94	0.46687	1.36059
2 (,, N/100)	10.25	40.26	1.01072	1.60487
3 (,, N/75)	16.59	51.24	1.21985	1.70961
4 (,, N/50)	24.89	76.62	1.39602	1.88434
5 (,, N/25)	55.14	150.69	1.74147	2.17808
6 (,, N/10)	312.81	213.74	2.49528	2.32988

TABLE 59. *(Continued)*

	Iodine left C (mg)	Iodine adsorbed x (mg)	log C	log x
Rice starch				
1 (About N/200)	1.13	25.13	0.05308	1.40019
2 (,, N/100)	5.37	45.14	0.72997	1.65456
3 (,, N/75)	11.71	56.12	1.06856	1.74912
4 (,, N/50)	29.77	71.74	1.47378	1.85576
5 (,, N/25)	85.40	120.44	1.93146	2.08077
6 (,, N/10)	312.81	213.74	2.49523	2.32988
Italian millet starch				
1 (About N/200)	0.49	25.38	$\bar{1}$.69020	1.40449
2 (,, N/100)	4.03	46.48	0.60531	1.60727
3 (,, N/75)	10.98	56.85	1.04060	1.75473
4 (,, N/50)	28.30	69.20	1.45179	1.84011
5 (,, N/25)	79.06	126.78	1.89796	2.10305
6 (,, N/10)	311.83	214.72	2.49392	2.33187
Barley starch				
1 (About N/200)	0.49	25.38	$\bar{1}$.69020	1.40440
2 (,, N/100)	2.93	47.58	0.46687	1.67742
3 (,, N/75)	8.30	59.54	0.91908	1.77481
4 (,, N/50)	22.20	79.30	1.34635	1.89927
5 (,, N/25)	68.81	137.03	1.83765	2.13682
6 (,, N/10)	315.49	211.06	2.49897	2.32440
Corn starch (Kingsford)				
1 (About N/200)	0.49	25.38	$\bar{1}$.69020	1.40440
2 (,, N/100)	—	—	—	—
3 (,, N/75)	9.76	58.07	0.98945	1.76395
4 (,, N/50)	29.52	71.98	1.47012	1.85721
5 (,, N/25)	95.16	110.68	1.97845	2.04407
6 (,, N/10)	314.27	208.23	2.49730	2.31865
Sample No. 3				
Potato starch (Kojima)				
1 (About N/200)	0.77	23.67	$\bar{1}$.88649	1.37420
2 (,, N/100)	4.39	43.92	0.64246	1.64246
3 (,, N/75)	8.05	56.36	0.90580	1.75097
4 (,, N/50)	18.54	77.10	1.26811	1.88705
5 (,, N/25)	49.78	144.45	1.69705	2.15972
6 (,, N/10)	265.47	215.70	2.42401	2.33385
Dog-tooth violet starch				
1 (About N/200)	—	—	—	—
2 (,, N/100)	5.12	43.19	0.70927	1.63538
3 (,, N/75)	12.20	52.22	1.08636	1.71784
4 (,, N/50)	31.23	64.42	1.49457	1.80902
5 (,, N/25)	94.67	99.55	1.97621	1.99804
6 (,, N/10)	—	—	—	—

TABLE 59. (*Continued*)

	Iodine left C (mg)	Iodine adsorbed x (mg)	log C	log x
		Wheat starch (Kojima)		
1 (About N/200)	0.98	23.42	$\bar{1}.99123$	1.36959
2 (,, N/100)	7.56	40.75	0.87852	1.61013
3 (,, N/75)	15.86	48.56	1.20030	1.68628
4 (,, N/50)	36.14	60.51	1.54580	1.78183
5 (,, N/25)	97.11	97.11	1.98726	1.98726
6 (,, N/10)	—	—	—	—
		Sorghum starch		
1 (About N/200)	0.85	23.55	$\bar{1}.92942$	1.37199
2 (,, N/100)	7.93	40.38	0.89927	1.60617
3 (,, N/75)	15.74	48.68	1.19700	1.68735
4 (,, N/50)	34.65	61.00	1.53970	1.78533
5 (,, N/25)	96.62	97.60	1.98507	1.98945
6 (,, N/10)	282.55	198.62	2.45109	2.29802
		Rice starch		
1 (About N/200)	2.56	21.84	0.40824	1.33925
2 (,, N/100)	7.69	40.63	0.88593	1.60885
3 (,, N/75)	12.20	52.22	1.08636	1.71784
4 (,, N/50)	22.33	73.32	1.34889	1.86522
5 (,, N/25)	44.90	149.33	1.65225	2.17415
6 (,, N/10)	266.20	214.96	2.42521	2.33236
		Italian millet starch		
1 (About N/200)	0.49	23.91	$\bar{1}.69020$	1.37858
2 (,, N/100)	3.54	44.77	0.54900	1.65099
3 (,, N/75)	8.78	55.63	0.94349	1.74531
4 (,, N/50)	23.06	72.59	1.36286	1.86088
5 (,, N/25)	64.90	129.32	1.81224	2.11166
6 (,, N/10)	268.40	212.77	2.42878	2.32791
		Barley starch		
1 (About N/200)	0.49	23.91	$\bar{1}.69020$	1.37858
2 (,, N/100)	2.68	45.63	0.42813	1.65925
3 (,, N/75)	6.83	57.58	0.83442	1.76027
4 (,, N/50)	20.50	75.15	1.31175	1.87593
5 (,, N/25)	71.98	122.24	1.85721	2.08721
6 (,, N/10)	274.01	207.16	2.43776	2.31630
		Corn starch (Kingsford)		
1 (About N/200)	0.49	23.91	$\bar{1}.69020$	1.37858
2 (,, N/100)	3.05	45.26	0.48430	1.65571
3 (,, N/75)	7.81	56.61	0.89265	1.75289
4 (,, N/50)	22.25	73.40	1.34733	1.86570
5 (,, N/25)	81.01	113.22	1.90854	2.05392
6 (,, N/10)	—	—	—	—

From these results, the constants $1/n$, k and k' were calculated by the method described before.

TABLE 59.

Constants of the FREUNDLICH's adsorption isotherms.

Starch	Concentration of iodine solution used was					
	Low			High		
	$1/n$	k	k'	$1/n$	k	k'
			Sample No. 1			
Potato (Kojima)	0.27312	27.344	0.18039	0.86381	3.991	1.55764
Dog-tooth violet	0.24008	28.420	0.14923	0.52800	10.173	0.39035
Wheat (Kojima)	0.28989	25.713	0.19047	0.43838	18.195	0.37591
Sorghum	0.60746	9.121	0.60591	0.37424	97.062	1.28756
Rice	0.59571	13.317	0.81572	0.37801	23.385	0.31840
Italian millet	0.29106	31.892	0 23815	0.39310	24.468	0.36974
Barley	0.30817	29.734	0.24988	0.34681	29.864	0.32878
Corn (Kingsford)	0.26227	29.245	0.17901	0.51247	11.314	0.38995
			Sample No. 2			
Potato (Kojima)	0.26094	24.001	0.14556	0.50678	10.817	0.35846
Dog-tooth violet	0.22835	30.298	0.14671	0.50919	10.301	0.34709
Wheat (Kojima)	0.25304	24.580	0.14116	0.69681	4.834	0.59526
Sorghum	0.56388	11.556	0.56813	0.37220	27.035	0.35362
Rice	0.32227	24.945	0.23110	0.46327	15.053	0.36935
Italian millet	0.25773	30.691	0.18206	0.46709	15.200	0.38292
Barley	0.29600	27.274	0.21073	0.36407	26.946	0.33321
Corn (Kingsford)	0.25901	30.871	0.18475	0.44949	15.221	0.33955
			Sample No. 3			
Potato (Kojima)	0.37125	25.874	0.33621	0.37100	28.867	0.37446
Dog-tooth violet	0.22116	30.074	0.13857	0.39247	16.689	0.25110
Wheat (Kojima)	0.32516	20.799	0.19657	0.46529	11.550	0.28738
Sorghum	0.25448	24.316	0.14103	0.56330	7.984	0.39093
Rice	0.55874	12.937	0.61384	0.35956	29.983	0.35938
Italian millet	0.28800	29.900	0.21860	0.43290	19.570	0.38924
Barley	0.30724	31.230	0.26079	0.39113	23.023	0.34320
Corn (Kingsford)	0.29450	30.581	0.23386	0.33545	25.925	0.26307

In the case of the adsorption of iodine by oxidized starch, the values of the constants 1/n, *k* and *k'*, when the concentration of iodine solution was low, were very different from those resulting when the concentration of iodine solution was high, as was seen in the case of the adsorption of iodine by original starch. In the case of the low concentration of iodine, in general, the constants 1/n, *k* and *k'* of oxidized starch sample No. 3, that is, the starch oxidized by ammonium persulphate, were the greatest, and the constants of oxidized starch sample No. 1, that is the starch oxidized by potassium permanganate, were the second, and those of oxidized starch sample No. 2, i.e. the starch oxidized by natrium perborate were the lowest. But, if the concentration of iodine solution was high, the opposite results were observed.

Comparing these results with those of adsorption of iodine by the original starch, it seems that the constants 1/n and *k'* of oxidized starch sample No. 3 were greater than those of original starch, but the constant *k* was smaller, when the concentration of iodine was low; however, in the case of high concentration of iodine, the opposite results were gained. In the case of oxidized starch of the other two kinds, i..e oxidized starches sample No. 1 and 2, not very different values of constants were shown from those of the original starch.

The coefficients of correlation between 1/n and *k*, and between 1/n and *k'* were calculated by the same method as described before.

TABLE 60.

Coefficients of correlation between 1/n and *k*, 1/n and *k'*.

	Concentration of iodine used was	
	Low	High
Oxidized starch sample No. 1		
Between 1/*n* and *k*	−0.9334	−0.4871
Between 1/*n* and *k'*	0.9439	0.6344
Oxidized starch sample No. 2		
Between 1/*n* and *k*	−0.9112	−0.9081
Between 1/*n* and *k'*	0.9920	0.8751
Oxidized starch sample No. 3		
Between 1/*n* and *k*	−0.8189	−0.8871
Between 1/*n* and *k'*	0.9787	0.6089

From these results, it is recognised that there is great correlation between 1/n and k, and also between 1/n and k′ in the case of the oxidized starch, and that the coefficient between 1/n and k is always negative, when the concentration of the iodine solution is low. In the case of a high concentration of iodine solution, however, only in the case of oxidized starch sample No. 2, is there great correlation, but with the other two oxidized starches, it is not so distinct. But, in all cases, the coefficient beween 1/n and k is always negative, and it is understood in general that when the constant 1 n becomes greater, then the constant k becomes smaller.

Chapter IV

Phosphoration of the Starches

According to SAMEC's studies, the starches are composed of amylose and amylopectin. The latter is the component that gives the solution of the starch its viscosity and it contains a large amount of phosphorus than amylose which has almost no phosphorus. The viscosity of the solution of the starch is due to the phosphorus containing component of the starch. Therefore, if phosphorus were combined with starch, the viscosity of the solution of the phosphorated starch should be higher than that of the original and the other physico-chemical properties should differ from those of the original starch.

The author intending the phosphoration of the starch carried out the following treatment. According to the method described by NEUBERG and KRETSCHMER (63), to 6 g of each starch were added 150 c.c. of water; each mixture was heated and made into a solution. To the cooled solution were added 16 g of calcium carbonate, the whole was cooled and shaken well whereupon a mixture of 5 g of phosphorus oxychloride and 10 c.c. of chloroform was added drop by drop. The product of the reaction was separated, washed throughly with water and dried in a desiccator of sulphuric acid of diminished pressure.

§ 1. Ash, phosphorus and calcium content of the phosphorated starches

The ash content of the phosphorated starch was determined by the ordinary method combusting the matter. The calcium content was determined by the precipitation of calcium oxalate from the solution of the ash in hydrochloric acid. The phosphorus content of the material was determined by IVERSEN's micro method (41).

TABLE 61.

Ash, phosphorus and calcium content of the phosphorated starch.

Starch	Ash (%)	Phosphorus (%)	Calcium (%)
Potato (Kojima)	0.92	0.351	0.218
Dog-tooth violet	0.82	0.216	0.056
Wheat (Kojima)	1.44	0.362	0.168
Sorghum	1.04	0.273	0.128
Rice	1.10	0.240	0.138
Italian millet	0.86	0.273	0.080
Barley	0.84	0.201	0.048
Corn (Kingsford)	0.74	0.225	0.072

The ash and phosphorus content described above were compared with those of the original starch taking the latter as 1.00.

TABLE 62.

Ratios of the ash and phosphorus content of the phosphorated starch to those of the original starch.

Starch	Ash	Phos-phorus	Starch	Ash	Phos-phorus
Potate (Kojima)	3.49	6.60	Rice	7.64	10.91
Dog-tooth violet	7.32	8.64	Italian millet	4.72	13 66
Wheat (Kojima)	3.21	6.13	Barley	11.20	8.04
Sorghum	8.81	13.00	Corn (Kingsford)	9.74	10.72

The starches increased in ash and phosphorus content greatly as a result of phosphoration. They came to contain calcium by the same treatment. The ash content reached to 3–11 times the original figure and the ratio to content in original starch was the greatest in the barley starch, then followed the starches of corn, sorghum, rice, dog-tooth violet, Italian millet, potato and wheat. The ash content lay between 1.44–0.74%, the ash content of wheat starch being the greatest, then followed those of rice, soghum, potato, Italian millet, barley, dog-tooth violet and corn. The order of the ash content in the treated starches was almost the reverse of the order of the ratio to ash content in the original starches. The content of the phosphorus of the phosphorated starches lay between 0.362–0.201%, which amounted to 6–14 times that of the original starches. The ratio of increase was the greatest in the Italian millet starch, then followed the starches of sorghum, rice, corn, dog-tooth violet, barley, potato and wheat. The absolute content of the phosphorus of the phosphorated starches was the greatest in that of wheat, followed by those of potato, sorghum, Italian millet, rice, corn, dog-tooth violet and barley.

Under the assumption that the combination between the phosphorus and the calcium occurred in the form $CaHPO_4$, the author calculated the equivalent numbers and the equivalent ratio of the phosphorus and the calcium as the following table shows.

TABLE 63.

Equivalent numbers and equivalent ratios of the phosphorus and calcium of the phosphorated starches.

Starch	Equivalent numbers in 100 g of the compounds		Equivalent ratio
	P	Ca	
Potato (Kojima)	0.01127	0.003194	3.527
Dog-tooth violet	0.006952	0.001397	4.975
Wheat (Kojima)	0.01165	0.004192	2.779
Sorghum	0.008786	0.003194	2.751
Rice	0.007723	0.003443	2.243
Italian millet	0.008786	0.001996	3.527
Barley	0.006469	0.001198	5.401
Corn (Kingsford)	0.007241	0.001797	4.031

The equivalent ratios of the phosphorus and calcium were always greater than 2. The value of the rice starch was the smallest, then followed those of the starches of sorghum, wheat, potato, corn, Italian millet, dog-tooth violet and barley. The quantities of the phosphorus combined with the starches were greater than those of the calcium combined. The excess of the phosphorus was considered to combine with the starches directly.

§ 2. *Viscosity of the solution of the phosphorated starches*

The viscosity of the solution of the starches is considered to be caused by the presence of amylopectin which contains phosphorus. Therefore it is to be expected that the viscosity of the solution of the phosphorated starches would show higher values than those of the original starches.

Given quantities of the phosphorated starch or the original starch and given quantities of water were mixed; the mixture was heated in a boiling water bath for 4 minutes; the solution was made up to 0.5% of the starch and the viscosity of the solution was estimated after 20 minutes, 1, 2, 3, 4, 5, 6, 7 and 8 days using the OSTWALD's viscosimeter at 20°C. The electrical conductivity of the solutions was also measured at 18°C. The cell constant of the one used was 0.7256 (18°C.).

TABLE 64.

Viscosity and electrical conductivity of solutions of phosphorated and original starch.

	Viscosity		Electrical conductivity	
	Original	Phosphorated	Original	Phosphorated
	Potato starch (Kojima)			
20 minutes	6.352	9.128	$0.864 . 10^{-5}$	$1.559 . 10^{-5}$
1 day	4.833	6.720	0.888	1.588
2 days	4.667	5.759	0.888	1.588
3 ,,	4.537	6.296	0.786	1.531
4 ,,	—	—	—	—
5 ,,	—	—	—	—
6 ,,	4.408	4.259	0.747	1.627
7 ,,	3.649	3.592	0.778	1.776
8 ,,	3.519	3.352	0.786	1.931

TABLE 64. (*Continued*)

	Viscosity		Electrical conductivity	
	Original	Phosphorated	Original	Phosphorated
		Dog-tooth violet starch		
20 minutes	1.315	7.945	1.109	1.282
1 day	1.277	7.776	1.126	1.327
2 days	1.296	8.147	1.126	1.300
3 ,,	1.277	7.982	1.076	1.354
4 ,,	1.333	7.667	1.109	1.213
5 ,,	—	—	—	—
6 ,,	1.259	6.907	1.177	1.464
7 ,,	1.259	5.964	1.221	1.550
		Wheat starch (Kojima)		
20 minutes	4.185	4.193	1.428	2.806
1 day	3.334	4.629	1.464	3.157
2 days	3.611	7.832	1.484	3.157
3 ,,	—	—	—	—
4 ,,	3.519	2.333	1.419	3.536
5 ,,	—	—	—	—
6 ,,	3.334	1.926	1.419	3.866
7 ,,	3.296	1.870	1.419	4.064
8 ,,	2.982	1.741	1.464	4.360
		Sorghum starch		
20 minutes	1.555	2.741	1.522	1.607
1 day	1.518	2.592	1.706	1.746
2 days	1.555	2.592	1.746	1.755
3 ,,	1.518	2.648	1.827	1.736
4 ,,	1.481	2.573	1.785	1.706
5 ,,	—	—	—	—
6 ,,	1.500	2.333	1.888	1.686
7 ,,	1.573	2.296	2.158	1.837
		Rice starch		
20 minutes	1.296	4.648	1.419	2.180
1 day	1.277	5.408	1.391	2.203
2 days	1.259	7.482	1.446	2.282
3 ,,	1.296	8.241	1.381	2.237
4 ,,	1.277	6.944	1.346	2.225
5 ,,	—	—	—	—
6 ,,	1.259	5.666	1.381	2.399
7 ,,	—	—	—	—
8 ,,	1.259	4.426	1.391	2.505

TABLE 64. (*Continued*)

	Viscosity		Electrical conductivity	
	Original	Phosphorated	Original	Phosphorated
		Italian millet starch		
20 minutes	1.407	5.137	1.026	1.446
1 day	1.407	4.926	1.050	1.464
2 days	1.407	4.852	1.026	1.464
3 ,,	1.389	4.722	1.067	1.474
4 ,,	1.371	4.667	1.083	1.511
5 ,,	—	—	—	—
6 ,,	—	—	—	—
7 ,,	1.371	4.093	1.118	1.685
8 ,,	1.333	3.963	1.177	1.746
		Barley starch		
20 minutes	1.203	2.519	0.434	0.786
1 day	1.222	2.592	0.428	0.709
2 days	1.203	2.556	0.441	0.888
3 ,,	1.222	2.500	0.400	0.848
4 ,,	—	—	—	—
5 ,,	—	—	—	—
6 ,,	1.203	2.704	0.400	0.763
7 ,,	1.185	2.129	0.305	0.786
8 ,,	1.222	2.463	0.318	0.778
		Corn Starch (Kingsford)		
20 minutes	1.185	2.944	1.265	1.984
1 day	1.203	2.519	1.195	1.941
2 days	1.185	2.774	1.187	1.858
3 ,,	1.185	2.774	1.203	1.827
4 ,,	1.185	2.556	1.187	1.941
5 ,,	—	—	—	—
6 ,,	1.166	2.407	1.134	2.102
7 ,,	1.148	2.148	1.169	2.214

It may be seen from the table that the viscosity of the solution of the phosphorated starch was higher than that of the original starch. The former value was twice, or more, that of the latter value. The electrical conductivity of the solution of the phosphorated starch was greater than that of the original starch. The former value was about twice that of the latter value.

The changes in viscosity and electrical conductivity of the solution of the phosphorated starch by aging were also observed. The viscosity was increased by the aging in the solutions of the phosphorated starches of the dog-tooth violet, rice and wheat; they reached to the maximum values and then decreased; the viscosity of the other cases was decreased by aging. The electrical conductivity of the solutions of the phosphorated starches increased generally, though there were observed slight daily changes.

By the phosphoration of the starch, the viscosity and electrical conductivity of the solution of the starch were increased; the viscosity of the solution of the phosphorated starch was decreased and the electrical conductivity was increased by the aging of the solution. It was considered that the particles of the phosphoraed starch had decreased in size or in their complexity of combination in solution.

To examine the changes in the viscosity and in the electrical conductivity of the solution of the phosphorated starch resultant upon differences in the time of heating of the solution, the following examinations were carried out. A 0.5% suspension of the starches was prepared, and portions were heated in a boiling water bath for 4 minutes, 1, 2, 3, 4 and 5 hours respectively with a reflux condenser. The viscosity and the electrical conductivity of the obtained solutions were estimated by the same apparatus under the same conditions as in former described determinations. The temperature of the heating was 96°C.

TABLE 65.

Viscosity and electrical conductivity of solutions of phosphorated and original starches prepared by different heating.

Time of heating	Viscosity		Electrical conductivity	
	Original	Phosphorated	Original	Phosphorated
		Potato starch (Kojima)		
4 minutes	5.315	5.538	$0.833.10^{-5}$	$1.540.10^{-5}$
1 hour	13.68	10.74	1.001	1.931
2 hours	8.112	6.500	1.354	2.421
3 ,,	5.684	6.500	1.607	2.604
4 ,,	4.333	5.315	1.878	2.806
5 ,,	3.741	4.388	2.037	3.227

TABLE 65. (*Continued*)

Time of heating	Viscosity		Electrical conductivity	
	Original	Phosphorated	Original	Phosphorated
	Dog-tooth violet starch			
4 minutes	1.111	3.592	1.373	1.152
1 hour	1.259	6.592	1.042	1.570
2 hours	1.333	6.277	1.177	1.858
3 ,,	1.333	5.056	1.282	2.315
4 ,,	1.352	4.074	1.419	2.422
5 ,,	1.333	3.519	1.806	2.819
	Wheat starch (Kojima)			
4 minutes	4.612	—	0.952	2.352
1 hour	13.55	18.15	0.992	2.363
2 hours	9.499	8.166	1.076	2.445
3 ,,	7.131	7.278	1.195	2.755
4 ,,	5.099	6.778	1.256	3.157
5 ,,	3.611	4.796	1.436	3.401
	Sorghum starch			
4 minutes	1.611	2.926	0.968	1.533
1 hour	1.592	2.241	1.177	1.817
2 hours	1.611	2.167	1.282	1.941
3 ,,	1.574	2.000	1.346	2.259
4 ,,	1.592	1.814	1.354	2.479
5 ,,	1.537	1.741	1.531	2.616
	Rice starch			
4 minutes	1.074	5.037	0.973	1.265
1 hour	1.407	7.314	0.888	1.686
2 hours	1.444	5.815	0.925	1.920
3 ,,	1.407	4.963	1.042	2.004
4 ,,	1.407	4.408	1.195	2.214
5 ,,	1.407	3.444	1.318	2.399
	Italian millet starch			
4 minutes	1.074	2.648	0.809	1.213
1 hour	1.407	5.705	0.825	1.858
2 hours	1.481	4.222	0.888	2.259
3 ,,	1.463	3.067	0.952	2.352
4 ,,	1.463	3.334	1.076	2.494
5 ,,	1.463	3.273	1.213	2.591

TABLE 65. *(Continued)*

Time of heating	Viscosity		Electrical conductivity	
	Original	Phosphorated	Original	Phosphorated
		Barley starch		
4 minutes	1.055	1.907	0.428	0.694
1 hour	1.185	3.222	0.469	1.265
2 hours	1.222	2.926	0.562	1.607
3 ,,	1.203	2.777	0.687	1.934
4 ,,	1.241	2.625	0.825	1.962
5 ,,	1.222	2.463	1.009	2.180
		Corn starch (Kingsford)		
4 minutes	1.222	2.167	0.519	0.888
1 hour	1.296	3.649	0.562	1.391
2 hours	1.241	3.500	0.709	1.706
3 ,,	1.277	3.334	0.944	2.203
4 ,,	1.315	3.334	0.920	2.102
5 ,,	1.277	2.777	1.126	2.591

Notwithstanding the length of the heating, the viscosity and the electrical conductivity of the solutions of phosphorated starch were higher than the same values of solutions of the original starches. By 1–2 hours' heating, the solutions of both sorts of starches gained the maximum values, subsequently by heating longer than 1–2 hours the viscosity of the solutions decreased little by little. This fact was especially marked in the case of the phosphorated starch. In the case of the original starch, it was not quite so marked and there were observed some starches which did not change in viscosity at all as a result of prolonged heating of the solutions. The electrical conductivity of the solutions of the phosphorated and the original starches increased in a regular manner concommitant with increase in the duration of the heating. The following considerations may be deduced from the above described facts, viz., that the particles of the starch had simplified their complex constitution by the heating of the solution and that this decomposition had given rise to the increase of the electrical conductivity and the decrease of the viscosity of the solutions.

§ 3. Electrometric titration of the phosphorated starches

It was a well known fact that starch is an electro-negatively charged substance and that in the field of an electrical current starch migrates to the anode. The electrical charge should be increased by the phosphoration of the starch which means the addition of an electro-negative charge to the starch. The electro-negative charge is considered to be neutralised by the addition of caustic alkali. Intending to determine the quantities of the natrium hydroxide necessary to secure electrical neutrality, the present author carried out electrometric titration of the phosphorated starches.

The suspensoid solution of the phosphorated starch was prepared by the mixing of 0.1 g of the material and redistilled water in a beaker. To the suspensoid solution was titrated N/100 natrium hydroxide solution by means of SHIBATA's electrometric titration apparatus.

TABLE 66.

Electrometric titration of the phosphorated starch.
The material used amounted to 0.1 g each.

Potato starch (Kojima)									
c.c. of the N/100 NaOH	—	0	0.5	0.6	0.7	0.8	0.9	1.0	1.1
Observed value	—	175	140	135	130	115	100	95	90
c.c. of the N/100 NaOH	1.2	1.3	1.4	1.5	1.7	1.8	1.9	2.0	2.5
Observed value	85	80	75	70	50	45	40	37	35
Dog-tooth violet starch									
c.c. of the N/100 NaOH		0	0.5	1.0	1.5	2.0	2.5	3.0	—
Observed value		190	170	140	60	50	40	35	—
c.c. of the N/100 NaOH		0	1.0	1.1	1.2	1.3	1.4	1.5	—
Observed value		190	140	120	100	85	72	60	—
Wheat starch (Kojima)									
c.c. of the N/100 NaOH		0	0.5	1.0	1.5	2.0	2.5	3.0	—
Observed value		220	205	130	95	65	55	50	—
c.c. of the N/100 NaOH		0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2
Observed value		205	200	185	150	130	120	115	110

TABLE 66. (*Continued*)

				Sorghum starch				
c.c. of the N/100 NaOH	0	0.5	1.0	1.5	2.0	2.5	3.0	—
Observed value	180	160	100	60	50	40	37	—
c.c. of the N/100 NaOH	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2
Observed value	160	155	145	135	125	110	95	85
				Rice Starch				
c.c. of the N/100 NaOH	0	0.5	1.0	1.5	2.0	2.5	3.0	—
Observed value	150	135	110	30	20	15	12	—
c.c. of the N/100 NaOH	0	1.0	1.1	1.2	1.3	1.4	1.5	2.0
Observed value	160	120	95	70	55	50	45	30
				Italian millet starch				
c.c. of the N/100 NaOH	0	0.5	1.0	1.5	2.0	2.5	3.0	—
Observed value	180	170	155	85	80	70	60	—
c.c. of the N/100 NaOH	0	1.0	1.1	1.2	1.3	1.4	1.5	—
Observed value	210	150	130	120	105	100	95	—
				Barley starch				
c.c. of the N/100 NaOH	0	0.5	1.0	1.5	2.0	2.5	—	—
Observed value	215	190	105	70	55	50	—	—
c.c. of the N/100 NaOH	0	0.5	0.6	0.7	0.8	0.9	1.0	1.1
Observed value	215	190	170	140	130	120	110	100
				Corn starch (Kingsford)				
c.c. of the N/100 NaOH	0	0.5	1.0	1.5	2.0	2.5	—	—
Observed value	205	180	120	70	50	45	—	—
c.c. of the N/100 NaOH	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2
Observed value	130	115	105	90	80	70	65	55

The figures were plotted in the coordinate system taking the quantities of the natrium hydroxide as abscissa and the observed values as ordinate. The inflexion point of the curve was determined from the figure and the value corresponding to the inflexion point was obtained. The quantities of natrium hydroxide corresponding to the inflexion point were considered to indicate the quantities necessary to neutralise the substance. The value was also calculated to the equivalent number of mg for 1 g of the starch.

TABLE 67.

Quantities of natrium hydroxide to neutralise the phosphorated starch.

Starch	c.c. of N/100 NaOH o. 1 g of material	mg of NaOH for 1 g of material
Potato (Kojima)	1.3	5.2
Dog-tooth violet	1.25	5.0
Wheat (Kojima)	0.9	3.6
Sorghum	1.0	4.0
Rice	1.15	4.6
Italian millet	1.1	4.4
Barley	0.75	3.0
Corn (Kingsford)	0.85	3.4

From these values the molecular equivalent of natrium hydroxide to 100 g of the phosphorated starch was calculated and the equivalent was compared with the difference between the equivalent of the phosphorus and the calcium of the phosphorated starch. If the phosphorus was considered to be contained in the phosphorated starch in the form of phosphoric acid, the quantities of phosphorus which were not saturated with the calcium could be obtained by the subtraction of the equivalents of the phosphorus and the calcium.

TABLE 68.

Difference of the equivalents of phosphorus and calcium and the equivalent of natrium hydroxide needed to neutralise phosphorated starch corresponding to 100 g of the materials.

Starch	Difference	Equivalent of NaOH
Potato (Kojima)	0.00808	0.0130
Dog-tooth violet	0.00556	0.0125
Wheat (Kojima)	0.00746	0.0090
Sorghum	0.00559	0.0100
Rice	0.00428	0.0115
Italian millet	0.00679	0.0110
Barley	0.00527	0.0075
Corn (Kingsford)	0.00544	0.0085

The equivalent of natrium hydroxide was markedly greater than that of the difference between the equivalent of the phosphorus and the calcium. The neutralisation of the phosphorated starch by natrium hydroxide required greater quantities of natrium hydroxide than the quantities of the phosphorus which were contained in free form in the molecule. The excess in the quantities of the natrium hydroxide was considered to be employed for the neutralisation of the negative charge of the starch molecule which was observed by the electrophoresis and other means. This consideration gives an one side recognisation of the negative character of the starch molecule.

Conclusions

The author had carried out his experiments using 14 starches obtained from 11 species of plants. These were the potato, dog-tooth violet, wheat, barley, common rice, common Italian millet, common sorghum, corn, cassava, buckwheat and arrowroot.

From the results of his experiments, the author has come to the following conclusions.

(1). By the comparison of the starches of the cereal plants and the starches of the tubers, it was observed that the ash content of the latter were higher than the ash content of the former. The ash content was seen to differ markedly according to the difference of the method of the manufacturing of the starches.

(2). The content of the phosphorus of the starches was 0.058–0.035%. The phosphorus content of the starches differed very markedly according to the method of the preparation of the starches. The treatment with natrium hydroxide solution seemed to diminish the phosphorus content of the starches.

(3). It was observed that the ash constituents of the starch had to play an important role in the construction of the starch and that the ratio of the ash constituents other than phosphorus, to the phosphorus was almost constant in each starch.

(4). The nitrogen content of the starches ranged between 0.004% and 0.05%, mainly 0.02% or so.

(5). The ratio of the phosphorus and the nitrogen of the starches of the tubers was markedly small in comparison to the same values of the cereal plant starches.

(6). By acetylation with acetic acid anhydride at its boiling point there were obtained the acetyl starch which was built up with 2 glucose residues and 7 acetyl groups or with a mixture of equal quantities of the triacetyl glucose and tetraacetyl glucose or with an aggregate of the heptaacetyl maltose.

By acetylation with acetic acid anhydride with pyridin at room temperature, there was obtained an aggregate of the triacetyl glucose.

The acetylation of the starch progressed in inverse proportion to the content of phosphorus. It was considered by the author that the starches of the cereal plants contained amylopectin which was more unstable to the action of heating than the starches of the tubers.

(7). By benzoylation of the starches, the compound which contains 3 benzoyl groups to 2 glucose residues or the compound whose ratio was 1.5 was the most easily obtained.

The results of acetylation and benzoylation of the starches showed the same tendency, viz., that the starches which are easily acetylated without heating are also easily benzoylatable.

(8). By the nitration of the starches, the author obtained compounds which were the aggregate of dinitroglucose, the aggregate of the mixture of equal quantities of dinitroglucose and mononitroglucose and the aggregate of the mixture of 2 dinitroglucose and 1 mononitroglucose.

(9). Comparing the results of acetylation, benzoylation and nitration of the starches, the author was able to say that the treatment of the starches with acid either hot or cold had effected some changes upon the constitution of the starch molecules.

(10). The mechanism of the hydrolysis of the starches by the action of diastase was shown to be expressed well by the author's equation.

$$\frac{1}{t^{k'}} \cdot \frac{x}{a(a-x)} = k \,.$$

The relation between log k and k' of the equation could be expressed by an equation of a straight line.

(11). No direct relation was observed between the electrical conductivity of the solution of the starches and the phosphorus content as has been already reported by SAMEC and HAERDTL. Neither were any direct relations observed between the conductivity and the

ash content of the starches nor between their conductivity and nitrogen content.

On the whole, however, the electrical conductivity of the solution of the starches seemed to be increased when there was an increase in the content of ash, phosphorus or nitrogen of the starch.

(12). The highest viscosity was observed in the case of the sorghum starch rather than in the potato. To the sorghum succeeded the starches of rice and Italian millet. By the aging of the solutions of the starches, the viscosity reached its maximum in 1–4 days, then a decrease was observed. The barley starch alone showed increasing viscosity by the aging, within the limits of the present investigation.

(13). In general, the influences of salts upon the viscosity of the solutions of the starches investigated may be summarised as follows. When the concentration of the salt was low, the viscosity of the solutions of some starches was increased, but when the concentration of the salt was increased, the viscosity of the solutions was decreased in all cases.

Comparing the effect of the cations added, that of the natrium ion was the smallest. There was an increase in the influence excited in the order kalium ion, barium ion and calcium ion. These facts coincide well with HOFMEISTER's series.

(14). The author was able to show that the protective action of the starches upon gold solution had an optimum limit in quantity. The gold value of the starches was 2–13.

(15). The heat liberated by combustion of the starches was about 3900 calories. No difference was found which could be ascribed to differences in place of formation of the starches, i.e. there was no difference in the heat of combustion between the starches formed in the part of a plant above the ground and those from an underground part of a plant. The heat of combustion was the greatest in the dog-tooth violet starch following which came those of corn, Italian millet, wheat, rice, potato, sorghum and barley.

(16). The values of the constants $1/n$, k and k' of the FREUNDLICH's adsorption isotherms varied when the concentrations of the solutions of iodine were different. The value of $1/n$ was lower in the case of a low concentration of iodine than in the case of a high concentration, the value of k was higher and the value of k' was lower. When the concentration of iodine was low, the values of $1/n$, k and k' were smaller in the case of the starches of the tuber plants

than in the case of those of the cereal plants and when the concentration of iodine was high the relation was reversed.

There were close correlations between 1/n and *k*, 1/n and *k'* when the concentrations of iodine used were low. Between 1/n and *k*, a negative correlation was observed. Between 1/n and *k'* a positive correlation was observed. However, when the concentrations of iodine used were high, a negative correlation between 1/n and *k* was observed; the coefficient of correlation between 1/n and *k'* was 0.4260 which is an insufficient correlation.

It was found that definite quantities of iodine amounting to about 1/10 of the constant *k'* were combined with the starch in a form not removable by washing with potassium iodide solution. The mode of combination between the starch and the iodine was supposed to be either the formation of an adsorbed compound, a solid solution or a chemical combination between them.

(17). Electro-dialysis of the starch particle was carried out by means of PAULI's electro-dialysator. Electro-dialysed starch was thus obtained.

As an effect of the electric current, reducing substances were separated from the starches and also substances which showed reducing power after hydrolysis by acid. The amount of the substances in the middle cell was the greatest, which suggested that the starches had separated mostly a particle so great that it could not pass through the dialysis membrane.

The phosphorus of the starches was caused to migrate to the anode by the electric current. The phosphorus seemed to be charged as an anion, which was a complex organic compound. But this organic compound of phosphorus was considered to have not the least reducing power.

(18). The phosphorus and nitrogen content of the starches were both decreased by electro-dialysis.

The starch particle was changed in its construction in some way as an effect of electro-dialysis. This agreed well with ROSENTHAL's, NEUBERG's and LOEB's reports.

(19). The electro-dialysed starches were acetylated more easily than the original. The acetyl electro-dialysed starches were considered to be the aggregates of tetraacetyl glucose.

The starches of the tubers were changed becoming more easily acetylated than those of the cereal plants. The content of the acetyl

group was higher in the case of the starches of the tubers than in those of the cereal plants.

(20). The electrical conductivity of the solutions of the electro-dialysed starches increased in the cases of the potato and wheat starches. However, the values decreased in the other starches.

(21). The viscosity of the solutions were increased by electro-dialysis over the corresponding values of the original starch solutions when the concentrations of the starches were low. When the concentrations of the starch solutions were higher, the viscosity of the electro-dialysed starches were always smaller than those of the original.

(22). By the determination of the gold value of the electro-dialysed starch, it was learned that electro-dialysis did not change the gold value of the starch, or in other words, electro-dialysis did not change the protective power of the starch at all.

(23). The adsorption of iodine by the electro-dialysed starch granule was investigated. The values of constants of FREUNDLICH's adsorption isotherms were calculated. The correlation between these constants was considered. When the concentrations of iodine used were low, there was a close negative relation between $1/n$ and k and a close positive relation between $1/n$ and k'.

(24). The hydrolysis of the electrodialysed starch was carried out and the two constants k and k' of the above given equation were calculated. In the case of hydrolysis of the electro-dialysed starches by the action of diastase, the mechanism was expressed fairly well by that equation and the relation between $\log k$ and k' could be expressed by an equation of a straight line.

(25). When the values of the two constants of the original and the electro-dialysed starches were compared, it was observed that the values of k were always markedly increased by the electro-dialysis and the values of k' were decreased. It was concluded therefore, that the starches were changed into a more easily hydrolysed form by the action of the electric current.

(26). Considering from the facts that the electro-dialysis (a) had decreased the phosphorus and the nitrogen content of the starches, (b) had separated the reducing and non-reducing substances from the starch which was hydrolysed into the reducing form by the action of acid, (c) had produced an easily acetylable substance and (d) had changed the starches into a more easily hydrolysed form by the

action of diastase, the author was able to deduce that the electro-dialysis had exerted some sort of changes upon the particles of the starches, which made the particles of the starches more susceptible to chemical reaction. The electro-dialysis was believed to decompose the starches very slightly.

(27). Oxidation of the starches was carried out by the use of three kinds of oxidizing agents, viz., potassium permanganate, natrium perborate and ammonium persulphate.

(28). The phosphorus content of the starches was decreased by the action of the oxidizing agents. The treatment with natrium perborate decreased the phosphorus content most greatly, the treatment with ammonium persulphate was the next and the effect of potassium permanganate upon the phosphorus content of the oxidized starch was the least.

(29). The oxidized starches were acetylated more easily than the original non-oxidized starches. The acetyl oxidized starch seemed to be an aggregate of tetraacetyl glucose.

(30). The viscosity of the solution of the starches was decreased by the action of the oxidizing agents. The starches decreased in the aggregation of their molecules as a result of the action of the oxidizing agents, the constitution of the starch molecule changed into a very simple form and the starch molecule was decomposed very much at the same time by the oxidizing agents.

(31). The adsorption of iodine by the oxidized starch granules was examined and the constants of FREUNDLICH's adsorption isothems were calculated.

Marked differences between the constants $1/n$, k and k' were observed in the case of the original and the oxidized starches treated by ammonium persulphate. However, in the case of oxidized starch of the other two kinds no marked differences were observed.

Between $1/n$ and k were observed negative correlations and between $1/n$ and k' were observed positive correlations.

(32). The starch was phosphorated by the action of phosphorus oxychloride and some properties of the compounds were examined.

(33). The starches increased greatly in ash and phosphorus content as a result of phosphoration. They gained calcium by the same treatment. The quantities of phosphorus combined with the starches were greater than those of the calcium. The excess of the phosphorus was considered to combine directly with the starches.

(34). The viscosity of the solution of the phosphorated starches was higher than that of the original starches. The electrical conductivity of the solution of the phosphorated starches was greater than that of the original.

The viscosity increased by aging in the solutions of the phosphorated starches to maximum values and then decreased, in general. The electrical conductivity of the solutions of the phosphorated starches increased generally, though there were observed slight daily changes.

(35). Notwithstanding the length of the heating, the viscosity and the electrical conductivity of the solutions of the phosphorated starches were higher than the corresponding values of the solutions of the original starches. At a definite duration of heating, the solutions of both the starches had shown maximum values, subsequently by longer heating the viscosity of the solutions was decreased gradually and the electrical conductivity of the solutions of both starches increased in a regular manner concomittant with an increase in the length of the heating.

(36). By the electrometric titration of the phosphorated starches, the author was able to conclude that the equivalent of natrium hydroxide need to secure electrical neutrality was markedly greater than that of the difference between the equivalents of phosphorus and calcium. The neutralisation of the phosphorated starches with natrium hydroxide required greater quantities of the natrium hydroxide than the quantities of the phosphorus which were contained in free form in the molecule. The excess of the natrium hydroxide was considered to be employed for the neutralisation of the negative charge of the starch molecule which was observed by electrophoresis and other methods.

Literature

1. ALEXANDER, Some Novel Aspects of Colloidal Protection, Colloid Chemistry, Vol. 1, 621, 1926.
2. AMBARD, Sur les lois des réactions monomoléculaires (réactions fermentaires - réactions catalytiques), Jour. chim. phys., 22, 402–412, 1925; Chem. Abst., 20, 608, 1926.
3. BALLOT, Xyloïdine, Rapport annuel sur les progres de la chimie, 4, 222–223, 1844; WALTON, A comprehensive Survey of Starch Chemistry, Vol. 1, Part 2, 104, 1928.

4. BÉCHAMP, Action des protosels de fer sur la pyroxiline et ses congénères, Compt. rend., 37, 134–135, 1853; Faits pour sevir à l'histoire de la fécule, du ligneux, de la gomme et de la dulcine, Compt. rend., 51, 255–258, 1860; Sur la xyloïdine et sur de nouveaux dérivés nitriques de la fécule. Annales, 3, 64, 311–344; WALTON, A Comprehensive Survey of Starch Chemistry, Vol. 1, Part 2, 104, 1928.
5. BECKMANN, Beiträge zur Prüfung des Honigs, Zeitschr. analyt. Chem., 35, 263–284, 1896; WALTON, A Comprehensive Survey of Starch Chemistry, Vol. 1, Part 2, 179, 1928.
6. BERL and SMITH, On some simple and mixed Esters of Cellulose, Jour. Chem. Soc., 27, 534–538, 1908.
7. BERCZELLER, Über Kolloidmembranen als Dialysatoren, Biochem. Zeitschr., 90, 302–304, 1918.
8. *BERGMANN and BECK, Notiz über Acetolyse von Polysacchariden, Ber.* deutsch. chem. Ges., 54, 1574–1578, 1921.
9. BERGMANN and LUDEWIG, Über die Halogenverbindungen der Stärke, Ber. deutsch. chem. Ges., 57, 961–963, 1924.
10. BEGMANN, KNEHE and LIPPMANN, Cryoscopic Investigation of acetylated Carbohydrates, Annales, 458, 93–101, 1927; Chem. Abst., 22, 392, 1928.
11. BERL and BÜTLER Zur Kenntnis der Stärkenitrate, Zeitschr. Ges. Schiess-u. Sprengstoffwesen, 5, 82–84, 1910; Chem. Abst., 4, 1556, 1910.
12. BERTHELOT, Action de l'acide azotique sur les carbures d'hydrogène et sur les alcools, Annales, 5, 9, 316–328, 1876; WALTON, A Comprehensive Survey of Starch Chemistry, Vol. 1, Part 2, 105, 1928. Sur la vitesse de propagation de la détonation dans les matières explosives, solides et liquides, Compt. rend., 100, 314–320, 1885; Jour. Chem. Soc., 48, 478, 1885.
13. BERTHELOT and VIEILLE, Chaleur de combustion et de formation des sucres, hydrates de carbone et alcools polyatomiques congénères, Compt. rend., 102, 1284–1286, 1886; WALTON, A Comprehensive Survey of Starch Chemistry, Vol. 1, Part 2, 120, 1928.
14. BIEDERMANN, Fermentstudien. 1. Das Speichelferment, Fermentforschung, 1, 385–436, 1919.
15. BILTZ, SAMEC's Kolloidchemie der Stärke, 390, 1927.
16. BLOEMENDAL, Beitrag zur Kenntnis der Stärkemehls, Chem. Zentralbl., 1, 176, 1907.
17. BÖESEKEN, BERG and KERSTJENS, Quelques observations concernant l'acétylation et l'acétolyse de la cellulose et de l'amidon au moyen d'anhydride acétique, Receuil des travaux chimiques, 35, 320–345, 1915; Chem. Abst., 11, 39–41, 1917.
18. BRACONNOT, De la transformation de plusiers substances vegétales en un principe nouveau, Annales, 2, 52, 290–294, 1833; WALTON, A Comprehensive Survey of Starch Chemistry, Vol. 1, Part 2, 103, 1928.
19. BRESTER, Recherches électrolytiques, Arch. neerlandises des exactes et naturelles, 1, 296–304, 1866; WALTON, A Comprehensive Survey of Starch Chemistry, Vol. 1, Part 2, 69, 1928.

20. BRIGGS, A Modification of the Bell-Doisy Phosphate Method, Jour Biol. Chem., 53, 13–16, 1922; Some Application of the Colorimetric Phosphate Method, Jour. Biol. Chem., 59, 255–264, 1924.
21. BRIGLE and SCHINLE, Kohlenhydrate, VII. Zur Kenntnis des Stärke-acetates, Ber. deutsch. chem. Ges., 62, 99–103, 1929.
22. BROWN and GLENDINNING, The Velocity of Hydrolysis of Starch by Diastase, with some Remarks on Enzyme Action, Jour. Chem. Soc., 81, 388–400, 1902.
23. BROWN and MILLAR, Maltodextrine; its oxidation-products and Constitution, Jour. Chem. Soc., 75, 308–315, 1899.
24. COPE and BARAB, "Nitron" as a Gravimetric Reagent for the Analysis of Substances used in Explosives, Jour. Amer. Chem. Soc., 39, 504–514, 1917.
25. CROSS, BEVAN and TRAQUAIR, Die niederen Acetylderivate von Stärke und Cellulose, Chemiker-Zeitung, 29, 527–528, 1905; Chem. Zentralbl., 2, 36, 1905.
26. CROSS, BEVAN and BEADLE, The Interaction of Alkali-cellulose and Carbon Bisulphide, Jour. Chem. Soc., 63, 837–845, 1893.
27. ESCALES and LEVY, Über die Verwendbarkeit und die katalytische Wirkungsweise aromatischer Sulfofettsäuren bei der Herstellung hochmolekular Ester, Kunststoffe, 13, 25–55, 64–68, 1923; Chem. Zentralbl., 3, 486, 1923.
28. EULER and MYRBÄCK, Verbindungen von Jod mit Bestandteilen der Stärke, Liebig's Ann. Chem., 428, 1–24, 1922; Chem. Abst., 16, 2427, 1922.
29. FERNBACH, Quelques observations sur la composition de l'amidon de pommes de terre, Compt. rend., 138, 428–430, 1904; Jour. Chem. Soc., 86, 1, 294, 1904.
30. FORD, Lintner's Soluble Starch and the Estimation of "diastatic power". Jour. Soc. Chem. Ind., 23, 414–422, 1904; Jour. Chem. Soc., 86, 2, 452, 1904.
31. FORD, Note on the Hydrolysis of Starch by Diastase, Jour. Chem. Soc., 85, 980–983, 1904.
32. FOUARD, Recherches sur les propriétés colloïdales de l'amidon, et sur le mécanisme de migration de l'amidon dans les végétaux, Annales, 21, 475–484, 1907; Chem. Abst., 1, 1781, 2312, 1907; Sure les propriétés colloidales de l'amidon, Compt. rend., 144, 501–503, 1907; Chem. Abst., 1, 1332, 1907.
33. FOUARD, Sur les propriétés de l'amidon en rapport avec sa forme colloidal, Compt. rend., 146, 978–981, 1908; Chem. Abst., 2, 2330, 1908.
34. FRANCIS, Limitations of Starch as an Accelerator, Jour. Ind. and Eng. Chem., 1, 678–679, 1909.
35. FRIESE and SMITH, Zur Kenntnis der Kartoffel-Stärke, I. Mitt. über Stärke von K. HESS und Mitarbeiten, Ber. deutsch. chem. Ges., 61, 1975–1982, 1928.
36. HAWORTH, HIRST and WEBB, Polysaccharides, Part II. The Acetylation and Methylation of Starch, Jour. Chem. Soc., 1928, 2681–2690.

37. HEIMROD, Zerlegung hochkomplizierter chemischer Verbindungen im schwankenden magnetischen Kraftfeld, Zeitschr. Elektrochemie, 19, 812–816, 1913; Chem. Abst., 8, 863, 1914.
38. HEYL, Über Malzdiastase und die Einwirkung von Kaliumphosphaten auf dieselbe, Jour. prakt. Chem., 86, 433–457, 1912; Chem. Abst., 7, 2228, 1913.
39. HOLMBERG, Stärkespaltung durch tierische Amylasen, Arkiv för kemi, mineralogi och geologi, 8, 33, 1–5, 1923; Jour. Chem. Soc. 126, 1, 691, 1924.
40. IRVINE and MACDONALD, Some Research Problems in the Carbohydrates.—Starch, Report of the British Association for the Advancement of Science, 90th Meeting, 40–45, 1922; Jour. Soc. Chem. Ind., 41, 363–364R, 1922.
41. IVERSEN, Zur Bestimmung des Phosphorgehalts kleinerer Mengen von Blutt und Plasma, Biochem. Zeitschr., 104, 22–29, 1920.
42. KARRER, Einführung in die Chemie der polymeren Kohlenhydrate, 1925.
43. KARRER and SMIRNOFF, Polysaccharide. 15. Die Konstitution der Diamylose und des der Cellulose zu Grunde liegenden Anhydrozuckers, Helv. chim. Acta, 5, 187–201, 1922; Chem. Abst., 16, 1747, 1922.
44. KARRER, Der Aufbau der Stärke und des Glykogens, Naturwissenschaften, 9, 399–403, 1921; Chem. Abst., 16, 2314, 1922.
Polysaccharide. 6. Die Konstitution der Stärke und des Glykogens, Helv. chim. Acta, 4, 263–269, 1921; Chem. Abst., 16, 63, 1922.
Polysaccharide. 8. Zur kenntnis der Stärke und der Amylosen, Helv. chim. Acta, 4, 678–699, 1921; Chem. Abst., 16, 64, 1922.
Polysaccharide. 16., Ber. deutsch. chem. Ges., 55, 2854–2863, 1922.
Polysaccharide. 20. Zur Kenntnis polymerer Kohlenhydrate, Helv. chim. Acta, 6, 402–409, 1923; Jour. Chem. Soc., 124, 1, 655, 1923.
45. KERB, Über eine Verbindung der Stärke mit Phosphorsäure, Biochem. Zeitschr., 100, 3–14, 1919.
46. KESSELER and RÖHM, Über die Salpetersäureester der Stärke, Zeitschr. angew. Chem., 35, 125–128, 1922; WALTON, A Comprehensive Survey of Starch Chemistry, Vol. 1, Part 2, 108, 1928.
47. KINDT, Über die Veränderung der Stärke durch Salpeter-Schwefelsäure, über Auffindung der Baumwolle in Leinwand, und über Schiessbaumwolle, Annalen, 70, 167–171, 1847; WALTON, A Comprehensive Survey of Starch Chemistry, Vol. 1, Part 2. 104, 1928.
48. LAER, Nouvelles recherches sur la vitesse de saccharification de l'amidon. 1., Academie royale de Belgique Societe chimique Bulletin, 1910, 611–641; Jour. Chem. Soc., 98, 2, 839, 1910.
2., Bulletin, 1910, 707–718; Jour. Chem. Soc., 100, 2, 28, 1911.
3., Bulletin, 1911, 84–109; 4., Bulletin, 1911, 305–320; Jour. Chem. Soc., 100, 2, 478, 1911.
6., Bulletin, 1911, 759–830; Jour. Chem. Soe., 102, 2, 148, 1912.
Sur une action spéciale exercée par la température sur la diastase saccharifiante du malt, Bulletin, 1912, 18–28; Chem. Abst., 7, 205, 1913.

49. LAW, Untersuchungen über Acetylierung, Chemiker-Zeitung, 32, 365–366, 1908; Jour. Chem. Soc., 82, 1, 732, 1902.

50. LIEBEN and REICHARDT, Über die Wirkung verschiedener Oxydationsmittel auf lösliche Stärke, Ber. deutsch. chem. Ges., 8, 1020, 1875.

51. LING, Malt Analysis, Jour. Inst. Brew., 8, 441–456, 1902; Jour. Chem. Soc., 94, 1, 321, 1908.

52. LOEB, Über das Verhalten der Stärke unter dem Einfluss der stillen Entladung, Biochem. Zeitschr., 46, 121–124, 1912.

53. LOEB and SATO, Die Beeinflussung von Enzymreaktionen durch die stille Entladung, Biochem. Zeitschr., 69, 1–35, 1915.

54. LÜERS and WASMUND, Über die Wirkungsweise der Amylase, Fermentforschung, 5, 169–235, 1922.

55. MALFITANO, Les matieres amylacees etidiees a l'aide de nos connaissances sur l'etat colloidal, Compt. rend., 143, 400–403, 1906; Jour. Chem. Soc., 90, 1, 804, 1906.

56. MALFITANO and CATOIRE, Les micelles d'amidon sont-elles des complexes à plusieurs degrés d'amyloso-phosphates et d'amyloso-silicates alcalino-terreux? Bull. soc. chim., Serie 4, 37, 1014–1027, 1925; Chem. Zentralbl., 2, 2279, 1925.

57. MICHAEL, Action of Acetic Anhydride and Acetic Chloride on Maize and Potato-starch, Amer. Chem. Jour., 5, 359–360, 1883; Jour. Chem. Soc., 46, 420, 1884.

58. MOESER, Über den Eiweißgehalt der Stärke und eine Methode der Herstellung eiweissfreier Stärkepräparate, Zeitschr. Hygiene u. Infektionskrankheiten, 83, 113–116, 1917; Chem. Zentralbl., 1, 437, 1917.

59. MÜHLHÄUER, Die höheren Saltpetersäureäther der Stärke, Dingler's polytechnische Journal, 284, 137–143, 1892; Jour. Chem. Soc., 64, 1, 6, 1893.

60. MÜLLER, Dialytische Lösung von Casein und Amylum, Jour. prakt. Chem., 103, 49–51, 1868; Chem. Zentralbl., 1868, 1055.

61. NAKAMURA, Chemical Studies on the Brewing Barley, Jour. Faculty Agric. Hokkaido Imp. Univ., 23, 29–86, 1928.

62. NEUBERG, Chemische Umwandlungen durch Strahlenarten. 2. Wirkungen des elektrischen Gleichstromes, Biochem. Zeitschr., 17, 270–292, 1909.

63. NEUBERG and KRETSCHMER, Weiteres über künstliche Darstellung von Kohlenhydratphosphorsäureestern und Glycerinphosphorsäure, Biochem. Zeitschr., 36, 5–14, 1916.

64. NORTHROP and NELSON, The Phosphoric Acid in Starch, Jour. Amer. Chem. Soc., 38, 472–479, 1916.

65. OKADA, Nitrostarch, Cellulose Ind. Tokyo, 3, 3–14, 1927.

66. PAYEN, Note sur la pyroxyline, le coton hypoazotique et la xyloidine, Compt. rend., 24, 85–89, 1847; WALTON, A Comprehensive Survey of Starch Chemistry, Vol. 1, Part 2, 104, 1928.

67. PEISER, Über die Zusammensetzung der Stärke, Zeitschr. physiol. Chem., 161, 210–217, 1926.

68. PELOUZE, Note sur les produits de l'action de l'acide nitrique concentre sur l'amidon et le ligneux, Compt. rend., 7, 713–715, 1838; WALTON, A Comprehensive Survey of Starch Chemistry, Vol. 1, Part 2, 100, 1928.

69. PREGL, Über die Acetylierung von löslicher Stärke, Monatsh. Chem., 22, 1049–1066, 1901; Jour. Chem. Soc., 82, 1, 135, 1902.

70. PRINGSHEIM and EISSLER, Beiträge zur Chemie der Stärke. 2. Über SCHARDINGERS krystallisierte Dextrine, Ber. deutsch. chem., Ges., 46, 2959–2974, 1913.

71. PRINGSHEIM and LANGHANS, Beiträge zur Chemie der Stärke. 1. Über krystallisierte Polysaccharide aus Stärke, Ber. deutsch. chem. Ges., 45, 2533–2546, 1912.

72. PRINGSHEIM and LASSMANN, Über Inulin und Glykogen, Ber. deutsch. chem. Ges., 55, 1409–1414, 1922.

73. PRINGSHEIM, LEIBOWITZ and SILMANN, Beiträge zur Chemie der Stärke, 14. Über Salpetersäure-Ester der Polyamylosen, Ber. deutsch. chem. Ges., 58, 1889–1893, 1925.

74. PRINGSHEIM and WOLFSOHN, Beiträge zur Chemie der Stärke, 10. Über den verschiedenen Aufbau der beiden Stärke-Bestandteile, Ber. deutsch. chem. Ges., 57, 887–891, 1924.

75. RASK and ALSBERG, A Viscometric Study of Wheat Starches, Cereal Chemistry, 1, 7–26, 1924; Jour. Soc. Chem. Ind., 43, 532B, 1924.

76. RECHENBERG, Über die Verbrennungswärme organischer Verbindungen, Jour. prakt. Chem., 22, 1–45, 1880; Jour. Chem. Soc., 40, 10–12, 1881.

77. REINSCH, Über einige explosive Substanzen, Repertorium für die Pharmacie, 3, 3, 6–20, 1894; WALTON, A Comprehensive Survey of Starch Chemistry, Vol. 1, Part 2, 104, 1928.

78. RITTER, Weisses Schiesspulver, Dingler's polytechnische Journal, 161, 146–147, 1861; WALTON, A Comprehensive Survey of Starch Chemistry, Vol. 1, Part 2, 104, 1928.

79. ROSENTHAL, Zerlegung hochkomplizierter chemischer Verbindungen im schwankenden magnetischen Kraftfeld, Sitzungsberichte der Akademie der Wissenschaften zu Berlin, 1908, 20–26; Jour. Chem. Soc., 1908, 2, 152.

80. ROSENTHALER, Über Verseifungszahlen von Stärkearten, Pharmazeutische Zentralhalle, 66, 631, 1925; Chem. Abst., 20, 307, 1926.

81. SADTLER, Nitrostarch as an Explosive, Metallurgical and chemical Engineering, 16, 361–364, 1917; Chem. Abst., 11, 1750, 1917.

82. SAMEC, Studien über Pflanzenkolloide, 2. Lösungsstabilität der Stärke, Koll. Beihefte, 4, 132–174, 1912/13.
Studien über Pflanzenkolloide, 6. Zur Kenntnis der Alkalistärke, Koll. Beihefte, 8, 33–62, 1916.
Sur l'hydrolyse enzymatique des amylophosphates naturels et synthétiques, Compt. rend., 181, 532–533, 1925; Chem. Abst., 20, 428, 1926.
Studien über Pflanzenkolloide, 18. Zur Kenntnis der Weizenstärke, Biochem. Zeitschr., 186, 337–359, 1927.

83. SAMEC, Kolloidchemie der Stärke, 1927.
84. SAMEC, Kolloidchemie der Stärke, 1927, 363.
85. SAMEC, Kolloidchemie der Stärke, 1927, 314–362.
86. SAMEC, Studien über Pflanzenkolloide, 23. Lösliche Stärken erhalten durch Einwirkung von Oxydationsmitteln, Koll. Biehefte, 28, 155–166, 1929.
87. SAMEC and BENIGER, Studien über Pflanzenkolloide, 26. Die Beziehungen zwischen Phosphor und Stickstoff in der Kartoffel- und Weizenstärke, Koll. Beihefte, 33, 95–102, 1931.
88. SAMEC and BLINC, Studien über Pflanzenkolloide, 24. Zur Kenntnis der Erythrosubstanzen, Koll. Beihefte, 30, 163–196, 1930.
89. SAMEC and HAERDTL, Studien über Pflanzenkolloide, 9. Zur Kenntnis der Alkalistärke, Koll. Beihefte, 12, 281–300, 1920.
90. SAMEC and HOEFFT, Studien über Pflanzenkolloide, 3. Entaschungs- und Lösungsvorgänge bei Stärke, Koll. Beihefte, 5, 141–210, 1913/14.
91. SAMEC and JENCIC, Studien über Pflanzenkolloide, 5. Zur Kenntnis der löslichen Stärke, Koll. Beihefte, 7, 137–171, 1915.
92. SAMEC and MAYER, Studien über Pflanzenkolloide, 13. Über synthetische Amylophosphorsäuren, Koll. Beihefte, 16, 89–98, 1922.
93. SAMEC and MAYER, Studien über Pflanzenkolloide, 10. Über die Einwirkung von Formaldehyd auf Stärke, Koll. Beihefte, 13, 165–192, 1921.
94. SAMEC and MINAEFF, SAMEC's Kolloidchemie der Stärke, 1927, 390.
95. SAMEC and SSAJEVIC, Sur la composition du glycogen, Compt. rend., 176, 1419–1421, 1923; Chem. Abst., 17, 2891, 1923.
96. SAPOZHNIKOV, Determination of the Molecular Weight of Nitrostarch, Jour. Russ. Physic. Chem., 35, 126–128, 1903; Jour. Chem. Soc., 84, 1, 402, 1903.
97. SCHUETZENBERGER, Action de l'acide acétique anhydre sur la cellulose, l'amidon, les sucres, la mannite et ses congénères, les glucosides et certaines matieres colorantes vévétales, Compt. rend., 61, 485–486, 1865; Ber. deutsch. chem. Ges., 2, 163, 1869.
98. SCHUETZENBERGER, Mémoire sur les dérvés acétiques des principes hydrocarbonés de la mannite et de ses isomères, et de quelques autres principes immédiats végétaux, Annales, 4, 21, 235–264, 1870; Jour. Chem. Soc., 25, 66–71, 1872.
99. SCHUETZENBERGER and NAUDIN, Sur les dérivés acétiques des substances hydrocarbonées, Compt. rend., 68, 814–818, 1869; Chem. Zentralbl., 1869, 681–683.
100. SHERMAN, WALKER and CALDWELL, Action of Enzymes upon Starches of different Origin, Jour. Amer. Chem. Soc., 41, 1123–1129, 1919.
101. SJÖBERG, Über einige neue Produkte der enzymatischen Spaltung der Stärke, Ber. deutsch. chem. Ges., 57, 1251–1256, 1924.
102. SKRAUP, Notizen über Cellulose und Stärke, Ber. deutsch. chem. Ges., 32, 2413–2414, 1899.
103. SKRAUP, GEINSPERGER, KNAFFL-LENZ, MENTER and SIRK, Über Stärke, Glykogen und Zellulose, Monatsh. Chem., 26, 1415–1472, 1905; Jour. Chem. Soc., 90, 1, 67–68, 1906.

104. SYNIEWSKI, Über die lösliche Stärke, Ber. deutsch. chem. Ges., 30, 2415–2418, 1897.
Über die lösliche Stärke, 2., Ber. deutsch. chem. Ges., 31, 1791–1796, 1898.

105. SYNIEWSKI, Untersuchungen über Diastase. 3a. Über die Geschwindigkeit der unter Vermittlung von α-Diastase verlaufenden Stärke-hydrolyse, Biochem. Zeitschr., 162, 236–244, 1925.

106. TADOKORO, On the Differences between Some Colloidal and Chemical Properties of Common and Glutinous Rice Starch, 2., Jour. Coll. Agric. Hokkaido Imp. Univ., 16, 91–123, 1926.

107. THOMAS, The Phosphorus Content of Starch, Biochemical Bulletin, 3, 403–406, 1913/14; WALTON, A Comprehensive Survey of Starch Chemistry, Vol. 1, Part 2, 58, 1928.

108. TIEBACKX, Starch. (Abstract), *Jour. Soc. Chem. Ind.*, *42*, *467A*, *1923.*

109. TRAQUAIR, The Manufacture and Properties of some Starch Esters, Jour. Soc. Chem. Ind., 28, 288–291, 1909.

110. TRYLLER, Beiträge zur Chemie der Kartoffelstärkefabrikation, Chemiker-Zeitung, 44, 833–834, 1920; Chem. Abst., 15, 1828, 1921.

111. WALTON, A Comprehensive Survey of Starch Chemistry, Vol. 1, Part 1, 1928.

111_1. PICTET, Thermal Depolymerization of Starch in Relation to Molecular Constitution, 9–15.

111_2. IRVINE, Methylation of Starches in Relation to Molecular Constitution, 16–23.

111_3. LING, Enzymic Hydrolysis of Starches in Relation to Constitution, 24–34.

111_4. PRINGSHEIM, Bacterial Degradation and Constitution of Starch, 35–50.

111_5. SAMEC, The Colloid-Chemical Properties of Starch in Relation to Chemical Constitution, 51–61.

111_6. KATZ, The X-Ray Spectrography of Starch, 68–76.

112. WALTON, A Comprehensive Survey of Starch Chemistry, Vol. 1, Part 2, 100–103, 1928.

113. WILL and LENZE, Nitrierung von Kohlehydraten, Ber. deutsch. chem. Ges., 31, 68–90, 1898.

114. ZECHMEISTER, Zur Einwirkung von Acetylbromid auf Cellulose, Ber. deutsch. chem. Ges., 56, 573–578, 1923.

115. ZSIGMONDY, Kolloidchemie, 4. Aufl., 1922, 175.

DER EINFLUSS DER EIERBEHANDLUNG MIT ZENTRIFUGIERUNG AUF DIE VERERBUNG BEI DEM SEIDENSPINNER

I. ÜBER EXPERIMENTELLE AUSLÖSUNG DER POLYPLOIDEN MUTATION

Von

Eisaku KAWAGUCHI

[Mit 4 Textabbildungen]

Inhalt

Einleitung. 111
1. Material und Technik 112
2. Ergebnisse 113
   a). Beeinflussung der Eier 113
   b). Störung des genetischen Verhaltens 115
   c). Häufigkeit des Auftretens der polyploiden Schmetterlinge . 117
   d). Beschreibung der polyploiden Tiere 118
      i). Triploid 118
      ii). Tetraploid 119
      iii). Hexaploid 121
   e). Nachkommenschaft der polyploiden Rassen 121
      i). F_1-Generation von tetraploiden Tieren 121
      ii). Die Rückkreuzungen von Tetraploid mit Diploid: 4n ♀ × 2n ♂ und 2n ♀ × 4n ♂ 122
   f). Morphologische Analyse der polyploiden Tiere 122
3. Schluss 129
4. Zusammenfassung 131
Literatur 132

Einleitung

Die zahlreichen Untersuchungen der letzten Jahre, die mit dem Problem der künstlichen Reize auf Pflanzen und Tiere sich befassen, haben ein neues Licht auf die moderne Genetik geworfen, und zwar

hat die Wirkung von Röntgen- und Radiumstrahlen, ultraviolettem Licht und Temperaturreiz einen interessanten Einfluss auf die Vererbung gezeigt. Die Zentrifugierung hat noch nicht eine so grosse Rolle für diesen Zweck gespielt. Es gibt, soviel ich weiss, nur zwei Versuche in Pflanzenreich; der eine wurde von STUBBE (1930) bei *Antirrhinum majus* berichte, bei welchem durch die Behandlung des jungen Sprosses mit Zentrifugierung Mutation erzeugt wurde, und durch den anderen wurde von KOSTOFF (1935) bei *Nicotiana langsdorffii* gezeigt, dass man durch die Behandlung der Samen kurz vor Keimung mit Zentrifugierung verschiedene Pflanzen mit heteroploiden und verdoppelten Chromosomen erhalten kann.

Im Tierreich haben TANAKA und KAWAGUCHI (1932) bisher nur eine vorläufige Mitteilung über die Wirkung der Eierbehandlung mit Zentrifugierung beim Seidenspinner berichtet. Es ist dabei eine Anzahl von triploiden, parthenogenetisch entwickelten und von Mosaik-Tieren durch den Zentrifugierungsschock aufgetreten. Wir haben also angenommen, dass diese unerwarteten Tiere wahrscheinlich durch die Unordnuug in den normalen ersten Entwicklungsvorgängen im Ei, namentlich in der Reifeteilung und Befruchtung, verursacht wurden. Die weiteren Versuche, die seitdem von mir allein fortgesetzt wurden, haben das vorher gewonnene Ergebnis bestätigt und die Auslösung der noch weiteren polyploiden Formen, nämlich der tetraploiden und der hexaploiden, gesichert. Hier seien nur diese und weitere Daten, um unsere vorläufige Arbeit zu erweitern und zu ergänzen, und auch die diesbezüglichen morphologischen Daten besprochen.

1. MATERIAL UND TECHNIK

Als Versuchsobjekte wurde die folgende Kombination der Genen benützt, um die mutierten Tieren zu unterscheiden: $p^M y/py$ ♀ × $p^S y$ ♂.[1] Für die weiteren Ergänzungsversuche wurden noch andere

1) Das sogenannte zweite Chromosom von 28 Chromosomen bei *Bombyx mori* besitzt folgende Gruppe Genen: p^S (Striped: gestreifte schwarze Raupenzeichnung) (Fig. 1, a, b), p^M (Moricaud: dunkel-schmutzige Raupenzeichnung) (Fig. 1, e), p^B (Black: schwarze Raupenzeichung), p (plain: ungezeichnete Raupen) (Fig. 1, g), P (Normal: normale Raupenzeichnung) (Fig. 1, f), Gruppe multipler Allelen, in Lage O Einheit; Y (Yellow: gelbe Haemolymphe) und y (white: weisse Haemolymphe) in Lage 25.6 Einheit (TANAKA, '27). Unter diesen Genen ist nur p^S in der Homozygote von der Heterozygote äusserlich zu unterscheiden, so dass die gestreifte schwarze Farbe in der Heterozygote etwas heller als in der Homozygote ist (Fig. 1, a, b).

Kombinationen benützt, nämlich pY ♀ × p^My/p^Sy ♂ und die reziproken. Hier wollen wir uns aber nur mit dem oben zuerst angegebenen Fall beschäftigen, weil er fast überstimmende Resultate gegeben hat. Gegebenen Falls soll auch von den anderen Kombinationen die Rede sein. Eine bis drei Stunden nach der Eiablage, nämlich während der Phasen der Reifeteilungen im Ei und der Befruchtung, *wurden die Eier durch Zentrifuge behandelt.*[1]

a b c d e f g

Fig. 1. a, Striped in der Homozygote (p^Sp^S); b, Striped in der Heterozygote (p^Sp); c, Striped in der Triploide (p^Spp); d, Striped-*Moricaud* (p^Sp^M); e, *Moricaud* (p^Mp^M od. p^M); f, *Normal* (PP od. Pp); g, plain (pp).

Ich benützte eine Zentrifugalmaschine "Ergos" (in der Goto-Fuundo Fabrik in Tokyo verfertigt). Die Zentrifuge läuft mit *einer Höchstgeschwindigkeit* von 3500 *Umdrehung in der Minute.* Ihr Durchmesser mit horizontal gestellten Bechern beträgt 16 cm, die Becher waren 9.2 cm lang. Die Zentrifuge lief bei jedem Versuche 10 Min.

2. ERGEBNISSE

a). Beeinflussung der Eier

Die Eier sind von einer so mächtigen, chitinigen Schale umschlossen, dass sie unter dem angewandten Atmosphärendruck bei unserem

1). Wie der zeitliche Verlauf der ersten Entwicklungsvorgänge im Seidenspinnerei *schon von mir* (1928) gegeben wurde, kommen die ersten Reifeteilung etwa eine Stunden nach und die zweite zwei Stunden nach der Eiablage zu Ende, und von diesem Zeitpunkt bis drei Stunden findet die Kopulation der Ei- und Spermakerne *und noch weiter danach die erste Furchungsteilung* statt.

Zentrifugierungsversuche gar nicht gequetscht wurden. Unter der Schale folgt ein dünnes homogenes Häutchen, welches unter dem Namen Membrana vitellina bekannt ist. Darunter liegt vor der Befruchtung noch ein dünnes Keimhautblastem. Das Keimhautblastem ist etwas dicker in der Umgebung des Eikernes. In der zentralen Region des Eies finden wir überwiegend Nahrungsdotterkugeln und Fettkugeln in grösseren und kleineren Formen. Zwischen diesen Dotter- und Fettkugeln liegt das Plasma als ein zartes Retikulum. Nun wurden die Eier durch die Zentrifugalkraft im Aussehen geändert, sodass sie zwei verschieden gefärbte Hälften zeigten. Nah-

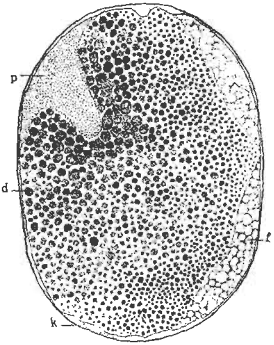


Fig. 2. Sagittalschnitt durch das Ei, 20 Stunden nach der Behandlung. d, Dotter-Zone: f, Fett-Zone: k, Keimhautblastem; p, Plasma-Zone.

rungsdottergranulen wurden nach dem äusseren Pol, Fettkugeln nach dem inneren Pol getrieben; deswegen bildeten sich zwei scharf von einander getrennte, eben begrenzte Zonen: Eine milchweisse Zone, eine klare, durchsichtige, gelbe Dottermasse, die unter den Schnittpräparaten keine Kugeln mehr zeigte. Unter den Schnittpräparaten haben wir aber noch eine Zone beobachtet, welche nach dem äussersten Pol getrieben wurde. Diese Zone ist wahrscheinlich die Masse des Plasmas, denn sie ist aus den ganz feinen Granulen entstanden. Es

ist mir bemerkenswert, dass das Keimhautblastem sehr widerstandsfähig ist. In den meisten Eiern war das Keimhautblastem nach der Behandlung fast unverändert erhalten. Aus den Schnittpräparaten des behandelten Eies konnten wir die Ausdehnung der drei Zonen, deren Volumen nicht umgerechnet wurde, ungefähr im Verhältnis von 1 Plasma-: 7 Dotter-: 2 Fett-Zone (Fig. 2) messen.

Nach der Behandlung mit Zentrifugierung geht eine Menge Eier zugrunde, doch bleibt eine geringe Zahl lebendig. Im Herbst 1933 sind ungefähr 276140 Eier mit Zentrifuge behandelt worden und 21300 (7.2%) von ihnen ausgeschlüpft. Beim Kontrollversuch 67.06%. Bei einem anderen Versuche (s105) sind 8.25% (Kontrolle 81.3%) und bei noch einem weiteren 20.49% (Kontrolle 95.79%) ausgeschlüpft. Bei den vorderen zwei wurden die Eier eine bis zwei Stunden nach der Ablage behandelt, aber bei dem letzteren wurden die Eier teilweise drei Stunden, teilweise auch eine bis zwei Stunden nach der Ablage behandelt. Daraus wissen wir, dass die *Eier, je älter sie werden, desto geringer zu Schaden kommen.*

b). Störung des genetischen Verhaltens

Im Herbst 1933 wurden Eier behandelt, die aus Weibchen mit der genetischen Konstitution p^My/pY gelegt und bereits von Männchen, die die Faktoren p^S und y homozygot hatten, befruchtet worden waren. Hieraus müssen wir zwei Sorten der F_1-Raupen zu gleichen Teilen erwarten, nämlich solche mit zwei übereinanderliegenden dunkel schmutzigen und schwarz gestreiften Körperfarben und weisser Haemolymphe (p^My/p^Sy) und nur solche schwarz gestreifter Körperfarbe und gelber Haemolymphe (pY/p^Sy), denn bei dem Weibchen der Schmetterlinge tritt der Faktorenaustausch nicht ein. Aus Frühlingszucht 1934 erhielten wir im Kontrollversuch ausnahmslos diese zwei Sorten von Tieren, von der ersteren 380 von der letzteren 292. Unter den 17193 F_1-Raupen aus den behandelten Gelegen im derselben Zucht haben sich aber ausser den erwarteten viele unerwarteten Raupe im fünften Stadium gezeigt, wie sich aus folgender Tabelle 1 ergibt.

Wie können nun diese unerwarteten Formen (5.9%) zustande kommen? Das könnten wir erklären, wenn man annimmt, dass entweder ein Eikern mit einem Richtungskern von einer Spermie oder

ein Eikern von zwei überzähligen Spermien[1] befruchtet wurde und also hier ein triploider Furchungskern entstanden ist.

Ist die Annahme richtig, so sind die folgenden Kombinationen der Genen in den triploiden Raupen möglich.

TABELLE 1. p^My/pY ♀ × p^Sy ♂

Nr. der Aufzucht	Behandelt						
	Zahl der erwarteten Raupen		Zahl der unerwarteten Raupen				
	Moricaud Striped white (p^Mp^Sy)	etwas hell striped Yellow (pp^SY)	Moricaud Striped Yellow	sehr hell Striped Yellow	dunkel Striped Yellow	dunkel Striped Moricaud white	Moricaud Yellow
s103	7326	6885	1166	212	182	62	943

Nr. der Aufzucht	Behandelt				Kontrolle			
	Zahl der unerwarteten Raupen			Summe	Zahl der erwarteten Raupen		Zahl der unerwarteten Raupen	Summe
	Moricaud white	plain Yellow	Mosaik		Striped Moricaud white (p^Mp^Sy)	etwas hell Striped Yellow (pp^SY)		
s103	75	77	265	17193	380	292	0	672

Ein E.K. + ein R.K. + ein S.K.

1. $p^My/pY/p^Sy$
2. $p^My/p^My/p^Sy$
3. $pY/pY/p^Sy$

Ein E.K. + zwei S.K.

4. $pY/p^Sy/p^Sy$
5. $p^My/p^Sy/p^Sy$

---

1). Nach den übereinstimmenden Berichten fast aller Beobachter dring[illegible] bei den Insekten normal mehrere Spermakerne in ein Ei ein. Ich beobachte auch bei einer chinesischen Seidenspinnerrasse unter 230 Eiern in zwei Stund[illegible] nach der Ablage 30 Monospermien, 84 Dispermien, 80 Trispermien, 17 Tetr[illegible] spermien, 3 pentasperimen und in einzelnen Fällen je 6, 8, 11 Spermakerne [illegible] einem Ei. In den übrigen dreissig Eiern konnte ich nirgend einen finden. [illegible] die erste Reifeteilung in diesen dreissig Eikernen nicht vollendet war, hing [illegible]heinlich noch an der Mikropyle an.

Phenotypisch sollen 1 Moricaud Striped Yellow, 2 Moricaud Striped white, 3 sehr hell Striped und Yellow erscheinen, weil einfaches p^S in den Triploiden viel heller (Fig. 1, c) als in den Diploiden zu erwarten ist, 4 dunkel Striped und Yellow, 5 dunkel Striped Moricaud erscheinen, weil voraussichtlich zweifaches p^S in den Triploiden viel dunkler als in den Diploiden werden soll. Die bei der 2. Gruppe erwartete diploide Form (p^My/p^Sy) kann man aber nicht phenotypisch unterscheiden, denn die Helligkeit von p^S wird gestört von der Dunkelheit von p^M.

Auf gleiche Entstehungsweise können wir auch weitere polyploiden Formen erwarten: tetraploide, pentaploide, hexaploide u. s. w., selbst wenn sie nach ihren Merkmalen nicht mehr von einander unterschieden werden.

Ausser diesen unerwarteten Formen treten aber noch einige in der Tabelle auf: Moricaud Yellow, Moricaud white und plain white. Von ihren Genotypen ohne Beteiligung der männlichen Gene kann man leicht ahnen, dass sie parthenogenetisch entwickelt sind.

Über die Analyse der Beziehung zwischen den genetischen Merkmalen und dem Geschlecht der polyploiden, sowie der parthenogenetisch entwickelten Tiere möchte ich im genetischen Teil der weiter erscheinenden Arbeiten ausführlich sprechen.

c). Häufigkeit des Auftretens der polyploiden Schmetterlinge

Die Zahlenverhältnisse der unerwarteten Charaktere zu den erwarteten kann man nicht direkt als die der polyploiden Tiere betrachten. Einerseits enthalten die erwarteten Klassen noch etwas polyploide Raupen, deren Merkmale von den diploiden Raupen nicht zu unterscheiden sind. Zum Beispiel ist p^M in der Homozygote von der Heterozygote in diploid, sowie von den zwei Heterozygoten-Klassen in polyploid kaum zu unterscheiden. Anderseits ist es möglich, dass ein trisomer Zustand in den diploiden Tieren durch Nichttrennung des zweiten Chromosoms vorkommt. Sie können vermutlich auch von den normalen diploiden nicht unterschieden werden.

Als Eigentümlichkeiten polyploider Rassen sind bei dem Seidenspinner Unfruchtbarkeit und unregelmässige Eiergrösse in der triploiden Rasse und Zunahme der Eiergrösse in der tetraploiden Rasse zu nennen, wie ich später besprechen will.

Gemäss diesen Eigentümlichkeiten wurden 846 von den ersten vier unerwarteten Falterformen untersucht. Darunter waren 183 (21.6%) tetraploid, 572 (67.7%) triploid und 91 (10.7%) diploid.

Zu einer sicheren Bestätigung der Häufigkeit des Auftretens der polyploiden Schmetterlinge habe ich daher aus einem anderen Zentrifugierungsversuche 626 Männchen cytologisch untersucht. Zu der Untersuchung bediente ich mich mit Zeitsparsamkeit der Zupfmethode, die mit Karminessigsäure ausgeführt wurde. Dabei zeigten 540 (86.3%) je 28 Chromosomen in den Reifeteilungen, waren also diploid, und 75 (12%) besassen 30–48 Chromosomen, waren also triploid, und ausserdem zeigten 11 (1.7%) annähernd 56 Chromosomen, waren also tetraploid. Nach Kreuzung mit einigen gewöhnlichen diploiden Männchen wurden 420 Weibchen in bezug auf Fruchtbarkeit und Eiergrösse untersucht. Darunter zeigten sich 347 (82.6%) diploid, 61 (14.5%) triploid und 12 (2.9%) tetraploid. Überhaupt hat sich nur ein einziges Weibchen von 17193 in dem Versuch (s103) als hexaploid gezeigt.

d). Beschreibung der polyploiden Tiere

Nun geben wir zunächst eine Beschreibung polyploider Formen hinsichtlich der vorläufigen zytologischen Beobachtung und der übrigen Eigentümlichkeiten.

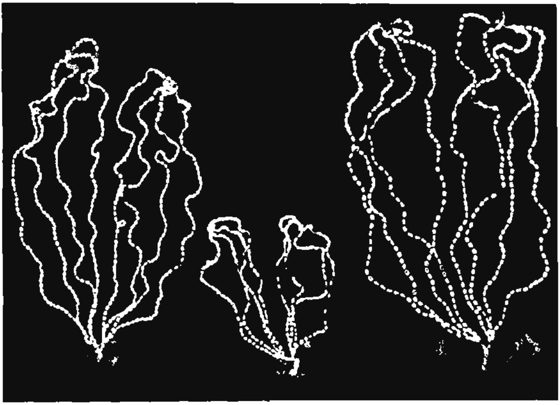
i). Triploid

Durch die zytologische Untersuchung wurde die Chromosomenzahl der ersten Spermatozytenteilung bei den triploiden Seidenspinnern als sehr schwankend erwiesen, es kamen 30–48 vor, während die diploiden 28 Chromosomen in der ersten Spermatozytenteilung boten (KAWAGUCHI 1928).

Zytologisch hatte ich noch keine gute Aequatorialplatte der Reifeteilungsfiguren für die triploiden Weibchen gefunden, konnte aber aus den Prophasenfiguren annehmen, dass sie mehr als 28 Chromosomen besassen.

Die triploiden Männchen sind ganz unfruchtbar in der Kreuzung mit den triploiden Weibchen, sogar auch mit den diploiden, trotzdem die Spermien in der Bursa copulatrix von Weibchen lebhaft sind. Wie die Männchen sind auch die triploiden Weibchen fast unfruchtbar und legen meistens die unregelmässig grösseren oder kleineren Eier ab (Fig. 3b, 4b). Bei den triploiden Männchen und Weibchen

finden wir auf den ersten Blick nirgendwo ein Vorzeichen der Intersexualität weder im Geschlechtsorgane noch in den sekundären Geschlechtsmerkmalen. Aber hierfür wäre noch eine eingehende Untersuchung erwünscht.



a b c

Fig. 3. Ovarien aus den polyploiden Schmetterlingen.
a, 2n ; b, 3n ; c, 4n.

ii). Tetraploid

Bei den Raupen ist es nicht leicht, nach den äusseren Merkmalen, die tetraploiden von den triploiden zu unterscheiden. Eine kleine Menge Weibchen von den unerwarteten Tieren legten gleichförmige und viel grössere Eier als die diploiden ab (Fig. 3c, 4c). Bei solchen Weibchen wurde auch aus den Reifeteilungsfiguren ihrer Ovarien-Eier festgestellt, dass sie tetraploid waren. Diese Figuren zeigten meistens 54 Bivalente und eine merkwürdige Quadrivalente, welche *ein Doppelkreuz oder einen rautenförmigen Ring* ergab. Diese tetraploiden Weibchen haben ausser einigen Ausnahmen meistens grosse Fruchtbarkeit gezeigt. Aus der Tabelle 7 findet man, dass der

Prozentsatz der Fruchtbarkeit 79.6% in tetraploiden Weibchen, aber 88,0% in diploiden betrug. Aller Wahrscheinlichkeit nach ist es darauf zurückzuführen, dass je zwei analoge Chromosomen immer starke Tendenz für Paarung haben.

Die diploiden, triploiden und tetraploiden Eier unterscheiden sich vor allem in der Grösse, wie Fig. 3–4 zeigen.

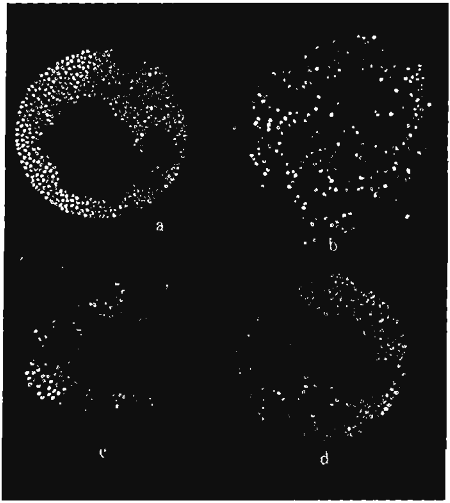


Fig. 4. Eier von den polyploiden Schmetterlingen.
a, 2n ; b, 3n ; c, 4n ; d, 6n.

Es ist sehr schwer, die tetraploiden Männchen von den triploiden zu unterscheiden, da sie fast keine besonderen Merkmale besitzen. Diese Männchen haben in Paarung mit tetraploiden Weibchen ziemlich wenige Furchtbarkeit (16.58%), wie in Tabelle 2 gezeigt, und ebenso wenig in der Kreuzung mit diploiden Weibchen (18.84%) (vgl. Tabelle 3).

Die Anzahl der Chromosomen in den ersten Spermatozyten wechselt zwischen 56 und 46. Diese Fluktuationen sind abhängig von der wechselnden Anzahl der Quadrivalenten und selten von dem Austritt der Univalenten.

iii). Hexaploid

Entsprechend meiner Erwartung hat sich ein einziges hexaploides Weibchen bei der F_1-Züchtung des ersten Versuchs (s103) ergeben. Sie ist schon mit einem diploiden Männchen gekreuzt worden und hat viel grössere Eier als die teraploiden gelegt (Fig. 4). Von 348 Eiern sind 144 ausgeschlüpft; 50 Weibchen und 59 Männchen konnten grossgezogen werden. Dieses Geschlechtsverhältnis, annähernd 1 ♀ : 1 ♂, ist nicht der Fall bei der Rückkreuzung (4n ♀ × 2n ♂), wie später erwähnt wird, bei der das Verhältnis sich immer von 2 ♀ : 1 ♂ bis zu 5 ♀ : 1 ♂ schwankend aufweist.

In der letzten Sommerzucht konnten noch einige hexaploide Tiere durch Behandlung von Eiern aus einer Kreuzung (4n ♀ × 2n ♂) erzielt werden.

Zytologische Untersuchung von F_1, die von hexaploiden Weibchen × diploiden Männchen stammten, hat festgestellt, dass sie alle tetraploid waren.

e). Nachkommenschaft der polyploiden Rassen

i). F_1-Generation von tetraploiden Tieren

Erst 1935 konnte ich zu unserem Glück endlich fünf Gelege Eier von der Paarung weiblicher und männlicher tetraploider Falter dadurch gewinnen, dass ich einige Männchen, die grössere Kopfbreite hatten, den Weibchen, die grössere Eier legten, zur Kreuzung brachte. Die Fruchtbarkeit dieser F_1 ist im wesentlichen geringer als die von ihren Reziproken (4n ♀ × 2n ♂), wie Tabelle 2 zeigt. Die tetraploiden Männchen konnten die diploiden Weibchen nur wenig befruchten; deshalb beruht die Ursache der geringeren Fruchtbarkeit wahrscheinlich auf diesen Männchen.

Ganz normal entwickelten sich die meisten Raupen bis zur Verpuppung, deren weitere Inzucht wegen der starken Herabsetzung der Fruchtbarkeit nunmehr zweifelhaft und tatsächlich unmöglich geworden war.

Wie die Tabelle zeigt, haben wir die beiden Geschlechter im annähernd gleichen Zahlenverhältnis von 1.7 : 1.0.

ii). Die Rückkreuzungen: 4n ♀ × 2n ♂ und 2n ♀ × 4n ♂

Für die erste Rückkreuzung 4n ♀ × 2n ♂ wurde die Aufzucht von 62 Paaren 1933–1935 gewonnen. Darunter zeigten sich alle Tiere als triploid, wie man erwartet, und zeigten ihre Geschlechter in den sehr verschiedenen Zahlenverhältnissen von 2: 1 bis 5: 1.

TABELLE 2. F_1 (4n ♀ × 4n ♂)

Nr. des Geleges	Anzahl der Eier	Zahl der im Ei zugrunde gegangenen Embryonen	Zahl der ausge-schlüpften Räupchen (Fruchtbarkeit)	Raupen bis zum Stadium der 4. Häutung ♀	♂
351P32	241	205	36 (14.94%)	24	6
P48	121	111	10 (8.26%)	3	3
P49	52	17	35 (67.31%)	16	10
P54	44	29	15 (31.09%)	3	5
P60	320	287	33 (10.31%)	7	9
Gesamt	778	649	129 (16.58%)	53	33

TABELLE 3. Rückkreuzung (2n ♀ × 4n ♂)

Nr. der Zucht	Anzahl der Eier	Zahl der im Ei zugrunde gegangenen Embryonen	Zahl der ausge-schlüpften Räupchen (Fruchtbarkeit)	Raupen bis zum Stadium der 4. Häutung ♀	♂
351P53	69	56	13 (18.83%)	3	4

Dagegen habe ich leider nur eine einzige letzte Rückkreuzun (2n ♀ × 4n ♂) gewonnen.

Wahrscheinlich kann man hier die beiden Geschlechter im Ve hältnis von 1: 1 erwarten.

f). Morphologische Analyse der polyploiden Tiere

Nun will ich eine vergleichende Untersuchung der Zellengrös und Zellenzahl von einigen Organen bei unseren diploiden und aut polyploiden Seidenspinnern machen und dann weiter auf ihre Körpe ... und Seidenfähigkeit näher eingehen.

Erst untersuchte ich Spermatozytenzellen und Eier als die gametischen Zellen und dann die Seidendrüsenzellen als die somatischen Zellen. Dabei können natürlich nur solche Zellen miteinander verglichen werden, die völlig homolog sind, die sich im gleichen physiologischen und genetischen Zustand unter der Einwirkung gleicher Bedingungen befinden. Den gleichen Zustand kann man in solcher Arbeit schwer erhalten, aber es wird eine Analyse im möglichst gleichem Zustand durchzuführen versucht. Daher sind die Fehler gross.

TABELLE 4. Spermatozytengrösse

	Zellengrösse $M \pm 3m$	$M_{Diff.} \pm 3m_{Diff.}$	Verhältnis gefunden (erwartet)	Σ
		Erste Spermatozyten		
2n	1.64±0.087	(3n-2n) 0.66±0.123	1.0 (1.00)	116
3n	2.30±0.087	(4n-3n) 0.85±0.156	1.4 (1.31)	124
4n	3.15±0.129		1.9 (1.58)	97
		Zweite Spermatozyten		
2n	0.94±0.035	(3n-2n) 0.36±0.043	1.0 (1.00)	50
3n	1.30±0.024	(4n-3n) 0.50±0.069	1.4 (1.31)	60
4n	1.80±0.065		1.9 (1.58)	36
			Einheit cm^2	

Die Zellengrösse. Es wurden die Spermatozyten der diploiden, triploiden und tetraploiden Männchen in den Stadien der Metaphase der I. und II. Reifeteilung gemessen, denn die Zellen sind zu dieser Zeit weitgehend abgerundet. Von jedem polyploiden Hoden wurden 30–150 Zellen mit dem Zeichenapparat auf Papier entworfen (Vergrösserung 800) und mit dem Planimeter der Inhalt sämtlicher Abbildungen gemessen. Die folgende Tabelle gibt also nur die Inhaltgrösse für die 800 malige Vergrösserung zusammen.

Die Werte besagen Folgendes. Die Mittelwerte von drei Formen zeigen untereinander eine sehr bedeutende Differenz in den ersten

sowie in den zweiten Spermatozyten. Ihre Zunahme des gefundenen Verhältnisses ist etwas mehr als die erwartete und verhält sich annähernd entsprechend der Kernplasmarelation.

Zur Vergleichung der Eiergrösse benutzte ich die Eier, die von den diploiden und tetraploiden Falten abgelegt wurden. Unten gebe ich nur die Messungen der Länge und Breite.

Das Verhältnis der Eiergrössen-Zunahme von 2n zu 4n ist etwas weniger als nach der Kernplasmarelation zu erwarten war.

TABELLE 5. Eiergrösse

	Länge $M \pm 3m$	Breite $M \pm 3m$	Σ
2n	1.23 ± 0.136	1.031 ± 0.165	50
4n	1.45 ± 0.122	1.186 ± 0.114	50
2n/4n	gefunden 1/1.18	1/1.15	
	erwartet 1/1.26	1/1.26	
			Masse in mm.

Volumenvergrösserung der Zellen der polyploiden Formen sieht man auch bei den Seidendrüsen. Aus den genug erwachsenen Raupen des letzten Stadiums sind die Seidendrüsen herausgenommen und sofort in CARNOY's Flüssigkeit fixiert worden. Die Seidendrüsenzellen zeigten die sechseckig längliche Gestalt; dieselben sind sehr regelmässig an einander gereiht. Es genügen zwei solcher Zellen, um die Drüse völlig zu umhüllen, so dass an der Seite der Seidendrüse eine zickzackartige Bindungslinie entsteht, die nach einer kurzen Behandlung der Drüsen mit CARNOY's Flüssigkeit sogar mit blossem Auge beobachtet werden kann. Die Grösse der Zellen variiert natürliche je nach ihrer Stellung in der Drüse. Die Messungen wurden an der Mitte des mittleren Teils (Sammeldrüse) mit den Mikrometer gemacht. Die Breite ist nach dem Durchmesser der ganzen Drüse und die Länge nach dem Zwischenraum jeder Zellengrenze gemessen worden.

Die Masse an dem Durchschnitt dreier Zellen aus je 25 Individuen der diploiden und triploiden Tiere (vielleicht auch einiger tetraploiden mit) bringt Tabelle 6.

Die Zunahme der Seidendrüsenzellengrösse von 2n zu 3n ist etwas mehr als die Erwartung nach der Kernplasmarelation, besonders in der Zunahmen der Länge. Wahrscheinlich kann man vermuten, dass die Nichtübereinstimmung mit dem idealen Verhältnis nach der Erwartung bei den Spermatozyten und Seidendrüsen auf der Fixierung oder irgendwelchen äusseren Bedingungen, besonders bei den letzteren auf der Vermischung der tetraploiden Individuen, beruht.

TABELLE 6.

Die Grösse der Seidendrüsenzellen

	Zellenlänge M±3m	Zellenbreite M±3m	
2n	0.77±0.064	1.87±0.113	
3n	1.03±0.125	2.09±0.089	
2n/3n	beobachtet 1.0/1.34	1.0/1.17	
	erwartet 1.0/1.14	1.0/1.14	
			Masse in mm.

TABELLE 7. Eierzahl

	Gebrütete Eier	Unbefruchtete Eier	Während der Entwicklung zugrunde gegangene Eier	Gesamt M±m	Fruchtbarkeit %
2n	421.60	10.60	47.0	479.2±20.96	88.0
4n	294.65	10.85	64.5	370.0±21.34	79.6

Für die Eiergrösse muss man den Einfluss von Dottermassen, die von Nährzellengrösse und -zahl bedingt werden, in Betracht ziehen.

Wir können jedoch sagen, dass das Verhältnis der Zellenzunahme bei Polyploidie annähernd der Kernplasmarelation entspricht.

Die Zellenzahl. Zunächst habe ich die Eierzahl an je 20 Gelegen aus den diploiden und tetraploiden Schmetterlingen in den schon erwähnten Versuchen gezählt und die Mittelwerte in folgender Tabelle gegeben.

Die Differenz der Mittelwerte der beiden Formen beträgt 109.2 ± 29.9. Also ist die Differenze 3.6 mal grösser als ihr mittlerer Fehler. Wir können demnach mit unbedingt genügender Sicherheit sagen, dass die Eierzahl der tetraploiden Schmetterlinge geringer als die der diploiden ist.

Weiter zeigen wir die Ergebnisse der Zählung an den Seidendrüsenzellen als den somatischen Zellen. Die Seidendrüsenzellenzahl variiert natürlich bei jedem Tiere, bleibt aber in derselben Raupe während ihrer ganzen Entwicklung wahrscheinlich gleich. Bei den Raupen einer chinesischen Rasse (Kokusan-Shi 101) habe ich an je 10 Tieren im zweiten Raupenstadium und in den ganz erwachsenen Raupen vergleichend die Zellen gezählt. Bei den ersteren war die Zellenzahl 204.1 ± 2.57 im mittleren Teil und 437.3 ± 5.42 im hinteren und bei den letzteren 217.0 ± 3.63 im mittleren und 433.2 ± 2.08 in dem hinteren Teil. Gesamtzahl des Mittelwertes 641.4 ± 6.0 im zweiten Stadium und 650.2 ± 4.18 im letzten Raupenstadium. Die Differenz der Mittelwerte und ihrer mittleren Fehler betrug 8.8 ± 7.31. Sie war weniger als dreimal so gross wie die mittleren Fehler. Wir können deshalb diese Differenz nicht als die Zunahme durch Zellteilung betrachten.

TABELLE 8.

Seidendrüsenzellenzahl bei den polyploiden Tieren

	Zellenzahl im		Gesamt	
	mittleren Teil, M ± m	hinteren Teil M ± m	M ± m	Σ
2n	228.1 ± 1.83	452.2 ± 4.98	680.3 ± 5.30	20
3n	160.0 ± 2.97	283.9 ± 5.68	443.9 ± 6.41	20

Nun vergleichen wir die Seidendrüsenzellenzahl an den triploiden Raupen, unter denen vielleicht auch einige tetraploide waren, aus dem Versuche (s263) mit der diploiden aus ihrem Kontrollversuch (unbehandelt).

Die Differenz der Mittelwerte der Gesamtzahlen von beiden 2n und die Differenz ihrer mittleren Fehler ist 136,4 ± 8.32. Diese Differenz kann man als eine zuverlässige betrachten, weil sie 16.3 mal so gross wie ihr Mittel-Fehler ist.

Die Ergebnisse dieser Messungen zusammenfassend, lässt sich sagen: Die Zellenzahl wird zuverlässig in den Eier- und Seidendrüsenzellen vermindert.

Körpergrösse. Das Zusammenwirken von Zellengrösse und Zellenzahl bedingt im wesentlichen die Körpergrösse. Für die Vergleichung der Einflüsse auf die Grösse der polyploiden Tiere habe ich lieber die Kopfgrösse als die Körpergrösse aufgenommen, weil die Raupenkörper unter Aussenbedingungen und Raupenstadien sich jeden Tag verschieden ändern, die Kopfgrösse aber durch die stärker chitinisierte Kopfkapsel innerhalb jedes Raupenstadiums fast gleich bleibt. Die Messung für die Kopfgrösse ist nur mit der Kopfbreite des Weibchens gemacht worden. In der folgenden Tabelle zeigen wir ausser dem Versuche s103 von der bisher erwähnten Frühlingszucht auch noch die Ergebnisse der Messungen aus einem Versuche von Herbstzucht (s263).

TABELLE 9. Kopfbreite

	$M \pm 3m$	$M_{Diff.} \pm 3m_{Diff.}$	Verhältnis gefunden (erwartet)	Σ
s103				
2n	3.38 ± 0.024	(3n-2n) 0.09 ± 0.03	1.000 (1.000)	220
3n	3.47 ± 0.018	(4n-3n) 0.08 ± 0.03	1.027 (1.143)	318
4n	3.55 ± 0.025		1.051 (1.262)	145
s263				
2n	3.23 ± 0.021	(3n-2n) 0.04 ± 0.02	1.000 (1.000)	175
3n	3.27 ± 0.012	(4n-3n) 0.19 ± 0.03	1.045 (1.143)	522
4n	3.46 ± 0.057		1.106 (1.262)	18

Wie die Tabelle zeigt, kann man einen ziemlich bedeutenden Unterschied zwischen Kopfbreite der polyploiden Tiere, aber nicht so gross wie der Zellengrösse-Unterschied, bemerken.

Puppengewicht. Das Puppengewicht wird natürlich durch Zusammenwirkung von Zellengrösse und Zellenzahl bedingt, ist aber auch durch Aussenbedingungen sehr veränderlich. Ungefähr kann man es doch im Vergleich benützten. Hier werden nur Weibchen fast in demselben Alter nach der Verpuppung in Milligramm gewogen, da das Puppengewicht, wie die Kopfbreite, nach dem Geschlecht verschieden ist.

Seidensekretionsfähigkeit (Seidengewicht). Das Seidengewicht ist wichtig für den praktischen Zweck. Hier wollen wir deshalb für die Seidensekretionsfähigkeit der polyploiden Raupen, und zwar nur von Weibchen, eine vorläufige Angabe machen.

TABELLE 10. Puppengewicht

	$M \pm 3m$	$M_{Diff.} \pm 3m_{Diff.}$	Verhältnis gefunden (erwartet)	Σ
s103				
2n	1.56±0.04	(3n-2n) 0.07±0.042	1.00 (1.0)	26
3n	1.63±0.01	(4n-3n) 0.02±0.022	1.04 (1.5)	345
4n	1.61±0.02		1.03 (2.0)	162
s263				
2n	1.49±0.13	(3n-2n) 0.01±0.016	1.00 (1.0)	176
3n	1 50±0.09	(4n-3n) 0.18±0.052	1.01 (1.5)	493
4n	1.67±0.05		1.12 (2.0)	18

TABELLE 11. Seidengewicht

	$M \pm 3m$	$M_{Diff.} \pm 3m_{Diff.}$	Verhältnis gefunden (erwartet)	Σ
s103				
2n	0.188±0.018	(3n-2n) 0.005±0.006	1.00 (1.0)	100
3n	0.193±0.006	(4n-3n) 0.011±0.110	1.02 (1.5)	318
4n	0.182±0.009		0.97 (2.0)	145
s263				
2n	0.159±0.006	(3n-2n) 0.003±0.007	1.00 (1.0)	175
3n	0.162+0.004	(4n-3n) 0.012±0.084	1.19 (1.5)	622
4n	0.174±0.084		1.28 (2.0)	18

Aus diesen beiden Tabellen findet man sehr wenige oder fast keine Differenzen zwischen den Puppengewichten sowie auch den Seidensekretionsfähigkeiten der polyploiden Formen. Das ist also aus dem Grunde, dass die *Zellenzahl* des Puppenkörpers sowie die Seidendrüsenzellenzahl in triploiden und auch in tetraploiden Formen atark herabgesetzt ist.

3. SCHLUSS

Im Pflanzenreiche wurden in den letzten Jahren die naturgemäss aufgetretenen polyploiden Rassen bei vielen Gattungen untersucht und in einigen Pflanzen sogar experimentell erzeugt. Im Tierreiche wurden sie aber nicht nur künstlich, ausser durch die Artbastardierung (FEDERLEY, '32), selten hergestellt, sondern auch in der Natur sehr spärlich gefunden.

Im folgenden wollen wir nun eine Übersicht über diese Fälle nur im Tierreich gewinnen.

Als ein sehr klassisches Beispiel haben wir bei *Ascaris megalocephala univalens* (2n = 2) eine tetraploide Rasse bivalens (2n = 4). Übersichtstabellen von HARVEY ('16) und WILSON ('25) zeigen uns einige ähnliche Beispiele: Eine Art, *Cypris fuscata*, von *C. reptans* und *C. incongruens* besassen die tetraploide Chromosomenzahl (WOLTERECK, '98, MÜLLER-CALÉ, '13, SCHLEIP, '90). In *Ophriotrocha puerilis* (KORSCHELT, '95, SCHREINERS, '06, GREGOIRE u. DETON, '06, DEHORNE, '10, 11) und *Helix pomatia* (vom RATH, '92, GODLEWSKY, '97, PROWAZEK, '02, BOLLES LEE, '96, '11, MURRAY, '98, ANCEL, '02) wurde auch eine tetraploide Rasse gefunden. In der Natur sind die tetraploiden Formen oft bei den rein oder fakultativ parthenogenetisch entwickelten Tieren bekannt. Die rein parthenogenetische Rasse von einer Phylopoden *Artemia salina* aus Capo d'Istria (ARTOM, '11, '12, '21), wie auch die von den Psychiden *Solenobia triquetrella* und *pineti* (SEILER, '23) sind tetraploid. Bei der obligatorischen Parthenogenese ist die polyploide sehr selten aufgetreten (*Bombyx mori*, SATO, '31).

Im Vergleich mit den tetraploiden Fällen wurden aber die Triploide und Hexaploide noch viel spärlicher gefunden.

Sie findet man auch oft bei den parthenogenetischen Rassen: die Triploide bei der von *Trichoniscus privisorius* (VANDEL, '27) und die Hexaploide bei der von *Daphnia pulex* (SCHRADER, '26, BENTA, '26). Bei Kreuzung der verschiedenen parthenogenetischen und bisexuellen Rassen von *S. triquetrella* erhielt SEILER ('27) eine Triploide.

Bei der genetischen Analyse hat BRIDGES ('21) bei *Drosophila melanogaster* die Triploide und später mit V. L. MORGAN (T. H. MORGAN u. a., '25) die Tetraploide gefunden und weiter GOWEN ('31) auch einen Stamm, bei dem infolge eines recessiven Gens im Chromo-

som III vererblich die Triploide auftreten, gezüchtet. Bei *Bombyx mori* hat HASHIMOTO vor kurzem tetraploide Falter mit dem hohen Temperaturschock erzeugt.

Die vorliegende Arbeit konnte ein sehr seltenes Beispiel, bei dem die polyploiden Rassen und zwar triploide, tetraploide sowie hexaploide experimentell erzeugt wurden, im Tierreich neu hinzufügen.

Nach der Erscheinung der von R. HERTWIG bekannten Kernplasmarelation führt eine Verdoppelung des Genoms zu einer Vergrösserung des Kernvolumens und damit auch des Zellenvolumens. So wurde der Riesenwuchs, den wir bei den vielen Polyploiden kennengelernt haben, direkt durch die Zellengrösse, d.h. die verdoppelten Genome hervorgerufen. Solche Vervielfachung des Genoms begleitet aber nicht immer den Riesenwuchs. Wir müssen manchmal Ausnahmen erwarten. Obwohl solche Ausnahme natürlich von vielen Faktoren abhängt, beruht sie oft auf der Zahl der Zellen, von denen der Körper gebildet wird. Wenn die Zellenzahl in den diploiden und polyploiden Formen nicht so stark konstant bleibt, sondern manchmal zunimmt, so führt die Verdoppelung des Genoms nicht zu Vergrösserung des Körpers.

Bei einigen Tieren halten einige Autoren das Konstantbleiben der Zellenzahl, die Eutelie (von MARTINI 1909 so genannt), stark fest.

Nach WETTSTEIN ist die Ursache der Seltenheit der Polyploidie im Tierreich auf die starke Eutelie zurückzuführen, durch die der physiologisch unbalancierte Riesenwuchs die polyploiden Individuen zum frühzeitigen Absterben führe. Nach der MULLERschen Auffassung (1925) ist diese Ursache dagegen in dem Geschlechtschromosomenmechanismus zu suchen.

Die Ergebnisse, die wir über die Zellengrösse und Zellenzahl gewonnen haben, zusammenfassend, lässt sich sagen: Die Zellengrösse nimmt im allgemeinen nach der Folge der Polyploidie zu und wird annähernd von der Kernplasmarelation bestimmt. Die Zellenzahl nimmt aber im Ei und in den Seidendrüsen ab. Sie hält Eutelie in anderen Organismen wahrscheinlich nicht streng fest, denn es fällt bei vergleichender Betrachtung diploider und polyploider Formen auf, dass Organe oder ganze Körper nicht so bedeutende Zunahme des Volumens nach der Folge der Polyploidie zeigen.

Der Japanischen Gesellschaft zur Förderung der Wissenschaften

(GAKUJUTSU-SHINKOKAI) bin ich für die Unterstützung zu Dank verpflichtet. Meinen Assistenten, den Herren S. OMURA und K. KOSHIYAMA, die mir bei Züchtung, Photographieren und Messungen immer geholfen haben, sei auch hier an dieser Stelle herzlichst gedankt.

4. ZUSAMMENFASSUNG

1). Durch Behandlung von Seidenspinnereiern kurz nach der Ablage (1–3 Stunden nach) mit Zentrifugierungsschock (10 Minuten lang mit 3500 Umdrehungen per Minute) wurden triploide, tetraploide und hexaploide Tiere erzielt.

2). Zur Unterscheidung der polyploiden Formen wurden hauptsächlich einige Gene, die zu einer multipleren Allele-Gruppe gehörten, und ein Paar Gene, die mit den ersteren gekoppelt waren, benützt. Ausserdem sind sie gemäss solchen Eigenschaften von Polyploiden, wie Fruchtbarkeit und Eiergrösse, unterschieden. Zur Festestellung der Häufigkeit des Auftretens der männlichen Polyploiden haben wir besonders zytologisch untersucht.

3). Hinsichtlich der Häufigkeit des Auftretens zeigten sich 12% von Männchen und 14.5% von Weibchen triploid, 1.7% von Männchen und 2.9% von Weibchen tetraploid. Von 17193 Raupen wurde nur ein einziges hexaploides Weibchen gefunden.

4). Durch Behandlung von Eiern aus einer Kreuzung (4n ♀ × 2n ♂) konnten noch einige hexaploide Tiere erzielt werden.

5). Bei den Triploiden ist das Weibchen fast nicht fruchtbar aber Männchen gar nicht. Bei den Tetraploiden zeigt das Weibchen in der Kreuzung mit Diploiden fast vollständige Fruchtbarkeit (79.6%), währed das Männchen in Paarung mit tetraploiden Weibchen viel geringere Fruchtbarkeit (16.58%) und ebensowenig in der Kreuzung mit Diploiden (18.84%) hat.

6). Triploide Weibchen legen sehr unregelmässig grössere und kleinere Eier, aber tetraploide Weibchen gleichmässig grössere Eier ab.

7). Keine Vorzeichen der Intersexualität kann man hier bemerken.

8). Die Spermatozyten-, Eier-, Seidendrüsenzellengrösse nimmt im allgemeinen nach der Folge der Polyploidie zu und wird annähernd von der Kernplasmarelation bestimmt.

9). Die Zellenzahl nimmt aber zuverlässig im Ei und in den Seidendrüsen ab. Sie hält Eutelie wahrcheinlich nicht streng fest.

10). In der Polyploidie des Seidenspinners zeigen darum die Kopfgrösse der Raupen, Puppengewicht sowie Seidensekretionsfähigkeit nicht so bedeutende Zunahme des Volumens.

Literatur

1. BRIDGES, C. B. Triploid intersexes in *Drosophila melanogaster*. Science. 54: 252–254. 1921.
2. FEDERLEY, H. Die Bedeutung der Kreuzung für die Evolution. Jenaische Zeitschr. f. Naturwiss. 67 (PLATE-Festschrift): 364–386. 1932.
3. GOWEN, J. W. Genetic nondisjunctional forms in *Drosophila*. Amer. Nat. 65: 193–213. 1931.
4. HARVEY, E. B. A review of the chromosome numbers in the Metazoa. Part I. Jour. Morph. 28: 1–63. 1916.
5. HASHIMOTO, H. Genetical studies on the tetraploid female in the silkworm. Bull. of the Imp. Sericult. Exp. Sta. 8: 359–381. 1933. (Jap. mit einer Zusammenfassung auf englisch)
6. KAWAGUCHI, E. Zytologische Untersuchungen am Seidenspinner und seinen Verwandten. I. Gametogenese von *Bombyx mori* L. und *Bombyx mandarina* M. und ihren Bastarden. Zeitschr. f. Zellforsch. mikr. Anat. 7: 519–552. 1928.
7. ——. "Black", ein Mutation der Körperfarbe beim Seidenspinner (*Bombyx mori* L.). Jap. Jour. Gen. 8: 98–106. 1933. (Jap. mit einer Zusammenfassung auf deutsch)
8. KOSTOFF, D. Chromosome alterations by centrifuging. Zeitschr. f. ind. Abst. u. Vererbungsl. 69: 301–302. 1935.
9. MORGAN, T. H., C. B. BRIDGES, A. H. STURTEVANT. The genetics of *Drosophila*. Bibliographia Genetica. 2: 1–262. 1925.
10. MULLER, H. J. Why polyploidy is rarer in animals than in plants. Amer. Nat. 59: 346–353. 1925.
11. SATO, H. Untersuchungen über die künstliche Parthenogenese des Seidenspinners *Bombyx mori*. IV. Biol. Zentralb. 51: 382–394. 1931.
12. SEILER, J. Geschlechtschromosomenuntersuchungen an *Psychiden*. IV. Die Parathenogenese der *Psychiden*. Zeitschr. f. ind. Abst. u. Vererbungsl. 31: 1–99. 1923.
13. ——. Ergehnisse aus der Kreuzung parthenogenetischer und zweigeschlechtlicher Schmetterlinge. Biol. Zentralb. 47: 426–446. 1927.
14. STUBBE, H. Untersuchungen über experimentelle Auslösung von Mutation bei *Antirrhinum majus*. I (Versuche mit Röntgenstrahlen, ultraviolettem Licht, Temperaturschocks und Zentrifugierungen). Zeitschr f. ind. Abst. u. Vererbungsl. 56: 1–38. 1930.

15. TANAKA, Y. Some remarks on symbols, multiple allelomorphism, crossing over and linkage groups in the silkworm. Jour. Dep. Arg. Kyushu Imp. Univ. 1: 275–279. 1927.
16. ——, und E. KAWAGUCHI. Über den experimental erzeugten triploiden Seidenspinner. Jap. Jour. Gen. 7: 186–187 (Jap.)
17. VANDEL, A. Gigantisme et triploidie chez l'*Isopode Trichoniscus* (*Spiloniscus*) *provisorius* Racovitza. Cpt. rend. des Séances de la Soc. de Biol. 20: 106–108. 1927.
18. WETTSTEIN, F. von. Morphologie und Physiologie des Formwechsels der Moose auf genetischer Grundlage. I. Zeitschr. f. ind. Abst. u. Vererbungsl. 33: 1–236. 1924.
19. ——. Die Erscheinung der Heteroploidie, besonders im Pflanzenreich. Ergebn. der Biol. Bd. II. Berlin. 1927.
20. WILSON, E. B. The cell in development and heredity. 3rd Ed. New York. 1925.

ARTIFICIAL INSEMINATION OF *BOMBYX MORI*

By

Seinosuke ÔMURA

[With 3 Text-Figures and 3 Tables]

Introduction

Artificial insemination (which is by no means the same as artificial fertilization) has played many important rôles in experimental embryology and breeding in some animals such as fishes, amphibians, echinoderms, etc. In fishes and even in some mammals it has now been introduced practically, from the economic point of view.

The method of artificial insemination is simpler in the animals whose eggs and spermatozoa come together outside the body than in those whose ejaculation is carried out inside the body. In the latter case the finer and the more complicated the construction of the sexual organs of both sexes is the more difficult is the carrying out of the artificial insemination. The character of the spermatozoa sometimes influences the method. Therefore there are not many examples of successful artificial insemination in insects.

Since a hundred or more years a method of artificial insemination has been desired eagerly among bee-culturists, for in bees this is the only method for breeding. Recently it was successfully carried out first by L. R. WATSON (1926) after many failures repeated by older investigators. He injected the semen taken out from the male sexual organ into the female organ with a fine injector settled on a micromanipulator. It needed delicate microtechnique at that time, but it has been improved now and demonstrated by some bee-culturists.

In Himenoptera there is one more example which was introduced by H. FEDERLEY (1929), although not published. That is the method tried by A. D. PEACOCK in Tenthredinidae, in which a glass tubule was used. It is notable that the seminal fluid taken out from the male sexual organ was used in both the above methods.

[Jour. Facul. Agr. Hokkaido Imp. Univ. Sapporo, Vol. XXXVIII, Pt. 2, Oct. 1936]

Only one example in Lepidoptera was introduced by FEDERLEY (1929), which was carried out by J. W. H. HARRISON (1916), who bred a hybrid between *Philosamia cynthia* female and *Philosamia promethea* male. He pushed the penis of *promethea* moth into the ductus bursae of *cynthia* and pressed the hindbody of the male.

For some years the present writer has also tried artificial insemination in *Bombyx mori* and he succeeded finally in 1932 (ÔMURA 1933) with glass tubules and again in 1934 (ÔMURA, 1935)(5) with a method analogous to HARRISON's. Furthermore studies on nearly all necessary conditions for the application of these methods were pursued.

The writer's efforts were first directed to examine the possibility of putting artificial insemination into execution in *Bombyx mori*, and in this direction he succeeded in developing reliable methods. In addition attempts were made to find as many methods as possible, because the final aim was to work out different methods practicable for various biological experiments. Consequently the central feature of the herein reported work is methodology.

This work was carried out under the guidance of Prof. Emer. K. SUDA and Prof. E. KAWAGUCHI. Hearty thanks are offered to both of them for their kind suggestions and encouragement throughout the course of the undertaking.

Materials

All the representative races of Japanese, Chinese and European silkworm moth cultured in the Sericultural Laboratory of the Hokkaido Imperial University and some from sericulturists in the country were employed at random. There is found scarcely any difference between the races in relative superiority as the materials, yet the larger moths such as found in some race-hybrids are better fitted for the experiment.

Methods

I. Glass tubule methods

A. Instruments

Not so complex instruments are necessary in these experiments as in the honey bee. A pincette and a pair of scissors for dissecting

and a set of injectors are enough. As the injector two sorts of glass tubules and an airpump were used. One of the glass tubules (Fig. 1: A) was used for the absorption of the seminal fluid, the other (Fig. 1: B) for the injection. Though the total length and the diameter of the basal part of both tubules are at the operator's option, it is recommended that the fine part of tubule "A" be made long enough to be able to include all the semen gathered up by it and that the fine and the thick parts of the tubule "B" both be made as short as possible; it is not very good to make the thick part of the tubule "A" too narrow nor to make the same part of the tubule "B" too wide. There is only one necessary condition about the relative dimentions of the tubules: let the fine part of "A" be so long that its end will reach to the boundary between the fine and thick parts of "B".

The end of both tubules is so capillarised, so fragile and so readily stopped up by the mucus of the seminal fluid after every use, that many of them must be prepared.

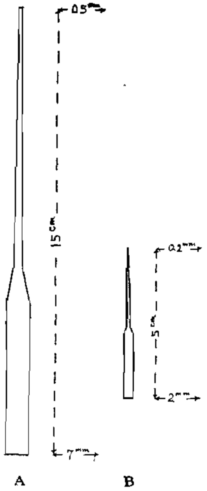


Figure 1. Two sorts of glass tubules. A. absorbing tubule. B. injecting tubule. Dimensions show the lengths and outer diameters roughly

For the airpump, such a one as that held by the foot and pressed by both hands is most suitable, as it is stable and strong in pressure. When the *seminal fluid* is not viscous, or the inner diameter of the end of the injecting tubule is large, the injection may be done without such a strong airpump but with an air bulb or even with an out-breathing press.

B. Methods for gathering the seminal fluid

The most important and essential point in the artificial insemination in Lepidoptera is the manner of gathering the seminal fluid.

The spermatozoa of silkworm moth have no activity in the vesicula seminalis or in the ampulla ductus deferentis under normal condition, while those ejaculated out into the bursa copulatrix have violent activity. This activity is brought about by the fluid secreted from the glandula prostatica of the male moth, which is analogous to the prostata of Mammalia (ÔMURA. 1935) (6).[1] Therefore, it was scarcely possible to succeed in the artificial insemination without activating the spermatozoa by mixing them with the prostatic secretion before injection. To gain such a mixture, there are two ways, which will be explained further on.

1. The seminal fluid in the bursa copulatrix of the copulated female

In natural copulation, the spermatozoa is usually mixed with the secretion from the glandula prostatica in the course of the ejaculation. Therefore, the complete seminal fluid that contains the spermatozoa which have violent activity as well as the ability of fertilization is found in the bursa copulatrix of the female who has made the copulation.

Under the natural conditions, the male moths continue the copulation with the females many hours and ejaculate several times, but the first ejaculation is completed within some 40 minutes after the beginning of the copulation under the normal temperature 25°C or so. So the most dense semen can be obtained immediately after 40–60 minutes copulation. When the semen is so viscous as not to be suitable for the experiment, it is recommended to keep the female for a while from the male after the copulation, in order to dilute the semen by the transmission of some part of the spermatozoa from the bursa copulatrix to the receptaculum seminis. Yet, to keep the female alone more than 10 hours in normal temperature is to be avoided, for the semen becomes too dilute to contain a sufficient quantity of spermatozoa for fertilization.

In order to gather the seminal fluid from the bursa copulatrix, the following procedure was employed. The female was dissected after the given duration of copulation and the bursa copulatrix was taken out. The spermatophora had been formed up making the membrane of the bursa to expand about its extremity. It has some

1) The details will be found in another paper.

rigidity and attains about half the size of a grain of wheat. So it was easily held by the thumb and forefinger of the left hand. Then the absorbing tubule was taken up in the right hand, and both membranes of the bursa and the spermatophora were penetrated by the point of the tubule. When the tubule was inserted well into the spermatophora the seminal fluid ascended gradually through the tubule and nearly the whole of the fluid could be sucked up into it. When that failed it became necessary to suck the fluid up into the tubule by gentle in-breathing. Then the head of the absorbing tubule which contained the seminal fluid was inserted into the wide part of the injecting tubule deep enough to reach to the entrance of the narrow part of it, and the fluid was transferred to the latter by gentle out-breathing.

Occasional coherence of some of the semen to the wall of the tubules may be partially avoided by soaking them in physiological salt solution before use.

2. The seminal fluid in the male sexual organs

The spermatozoa have no activity in the semen taken from the vesicula seminalis or from the ampulla ductus deferentis, but if a trace of the prostatic secretion is added there they become as vivid as they are usually in the semen which is ejaculated out in the natural copulation, and gain the ability of fertilization.

In order to gather the semen from these organs, an analogous process to that of the first method was repeated. This case is more difficult than in the first method, as the organs are more delicate and smaller than the female one. It was very difficult to hold them by the fingers, hence they were set on the tip of a finger.

After the gathering of the semen, one must add a trace of the prostatic secretion to it. The glandula prostatica is a small duct, which has about the same diameter as the end of the absorbing tubule. Therefore, all of the secretion of this gland could not be sucked up into the tubule, but some of it could be gathered after having, with the point of the tubule, stirred up the gland placed on a finger tip. The prostatic secretion may be sucked up first and then the semen. It was not necessary to mix the secretion previously with the spermatozoa, for they were mingled gradually by the movement of the spermatozoa which had obtained activity in contact

with the secretion. The two sorts of fluid sucked up in the same absorbing tubule were transferred to the other as in the former case.

Using this method, the seminal fluid taken into the tubule is less than in the former method, for it is difficult to gather all of it.

C. Method of injection

The injecting tubule with the seminal fluid was connected to the gum tube of the injector, or the airpump. Then the end of it was inserted into the ductus bursae of a given female. The airpump was pressed by an assistant. When the semen was dilute enough and the inner diameter of the end of the tubule was prepared not too small and no coherence of the semen on the wall of the tubule occurred, light pressure was enough for the injection. In several trials the writer succeeded only with out-breathing. But in cases when the conditions were not so favourable, strong pressure was necessary.

In practice, it is most difficult to insert the tubule into the ductus bursae. To acquire skill in this technique, it is advisable to practice it with a needle instead of a tubule. It requires skill also to inject all of the semen from the tubule into the bursa copulatrix with the air pressing. Because, if excess pressure was exerted the bursa was broken and the semen was pushed out into the body cavity. Moreover, the insemination was difficult of success unless a part of the semen touched the entrance of the ductus seminalis, otherwise the progression of the spermatozoa to the receptaculum seminis did not occur.

Fig. 2. shows several forms of the bursae copulatrices which have received the semen injected naturally by the ejaculation and artificially by the glass tubule. In the former it is notable that the outlet of the spermatophora is located close to the entrance of the ductus seminalis and the semen touches it. A in Fig. 2. is such a natural form. In the case of artificial injection several forms of the bursae are shown, of which B is the most ideal one and is very like the natural case. But there is not so much semen as in the natural ejaculation, therefore, in practise such forms as C and D are recommendable. D represents a case when a little air is added by a little over-pressure and the semen is returned back so as to touch the entrance of the ductus seminalis. C represents the case

when no air is added as in B, the injection having been stopped just before the finish. E and F are examples of failures. In the former case the pressure is intermediate between C and D, in the latter there is loaded over-pressure. In both cases no spermatozoon can progress to the receptaculm seminis, because no part of the semen whatsoever touches the entrance of the ductus seminalis.

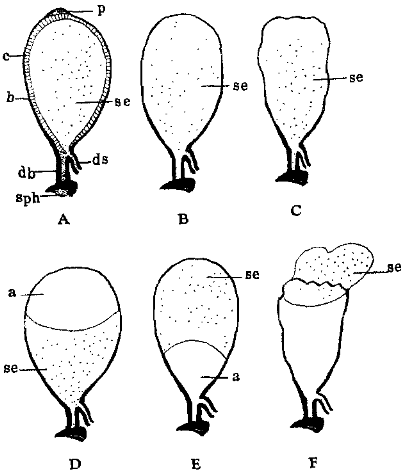


Figure 2. Models of the bursa copulatrix: A.... naturally mated, B-F.... artificially inseminized, B, C, D.... successful cases, E, F.... unsuccessful cases. a. air, b. bursa copulatrix, c. spermatophora, db. ductus bursae, ds. ductus seminalis, p. pearly body of spermatophora, se. semen, sph. spermatophragma.

The techniques described above appear very delicate, but it is not difficult to finish all the treatments, from the dissection to the injection, within five minutes. In 1934, the present writer measured 1.5–5 minutes which was consumed in a trial by the first method.

II. Artificial mating method

The relation between ejaculation and duration of mating in silkworm moth has been made clear by MACHIDA and WATANABE (1927). In normal temperature, by some 5 minutes mating the male moth is stimulated to ejaculation, which is finished normally even if the pairing is separated. So that one can see the figure of natural ejaculation by drawing out the penis after some 5 minutes mating. In fact, it is thus shown that the ejaculation of spermatozoa begins at 15–20 minutes after the beginning of the mating and lasts about 10–15 minutes.[1]

This principle has been applied, by the writer, to artificial insemination. The male was separated from the female after some 20 minutes mating, and the penis was inserted into the ductus bursae of a given female and kept in that position during 20 minutes or more. All the procedure was carried out by the fingers. So this method needed no instrument.

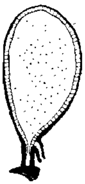


Figure 3. Spermatophora misformed by artificial mating method.

This is a simple method, but is hard to practice. As the penis is very small, short and brittle, it is difficult to insert it into the ductus bursae. Moreover the penis must be put deep enough into the ductus, and the paired individuals be held in such a posture as to receive no unfavourable effect which disturbs the ejaculation. In this experiment, the writer has some examples which had received nearly complete spermatophora but no spermatozoon proceeded to the receptaculum seminis. This may be attributed to the fact the opening of the spermatophora could not reach to the entrance of the ductus seminalis, owing to an insufficient insertion of the penis. Fig. 3 shows a misformed spermatophora.

Results of the experiments

I. The rate of success in the experiments

Since 1932, the writer has tried many experiments on artificial insemination. The rate of success in those experiments was not constant, being greatly influenced by many factors.

---

1) *The details will be found in another paper.*

TABLE 1.

Percentage of success in artificial insemination.

Method	Series of experi-ments	Date	Indi-viduals experi-mented	Indivi-duals which received *semen*[1]	Indi-viduals ferti-lized	% of suc-cess	Remarks
First glass tubule method	I	Nov. '32	13	7	3	23.1	Sperm were taken from the ♀♀ immediately after 3 hours copulation at 25°C.
	II	July '33	4	4	0	0	Sperm were taken from the ♀♀ kept alone 15 hours at 27°C after 1 hour copulation at 25°C.
	III	,,	2	2	1	50.0	Sperm were taken from the ♀♀ kept alone 10 hours at 10°C after 1 hour copulation at 25°C.
	IV	,,	12	1)	6	50.0	Sperm were taken from the ♀♀ immediately after 30 minutes copulation at 25°C.
	VII	July '34	10	10	7	70.0	Sperm were taken from the ♀♀ immediately after 30–60 minutes copulation at 25°C.
Second glass tubule method	VIII	,,	11	10	8	72.7	Sperm were taken from the vesiculae seminales of non-mated male moths.
	IX	,,	10	8	3	30.0	Sperm were taken from the vesiculae seminales of the pupae 2 days before emergence.
	XIII	Nov. '34	5	5	4	80.0	Sperm were taken from the ampullae ductuum deferentium of non-mated male moths.
Artificial mating method	XX	Oct. '34	4	2	1	25.0	
	XXI	,,	8	2	0	0	
	XXII	,,	7	2	1	14.3	

1) Involves the individuals which received the sperm in their bursae copulatrices, disregarding whether the eggs were fertilized or not.

The results are summarised in Table 1. As is shown, some individuals are found into whose bursae copulatrices seminal fluid was injected without any resultant fertilization. Many of them were injected with seminal fluid in such manners as shown in Fig. 2 (E and F) and Fig. 3, while some of them had too little a quantity

TABLE 2.

Total number, fertility and hatchability of eggs per batch.

Materials . . . . Akajyuku (a Japanese race)

Series of experiments	No. of batch	Deposited eggs	Fertilized eggs	Hatched eggs	Fertility (%)	Hatch-ability (%)
VII	3	451	334	317	74.1	94.9
	§ 6	685	667	582	7.4	87.3
	7	166	40	38	24.1	95.0
	8	606	557	522	91.9	93.7
	10	484	202	181	41.7	90.0
	§ 11	274	162	131	59.1	80.9
	12	433	11	4	2.5	36.4
VIII	1	162	14	12	8.6	85.7
	§ 2	545	499	300	91.5	60.1
	3	286	203	196	71.0	96.6
	§ 4	562	525	514	93.4	97.9
	5	496	47	43	9.5	91.5
	6	*395*	*343*	*280*	*86.8*	*81.6*
	8	454	369	337	81.3	91.3
	10	601	560	515	93.2	93.8
IX	§ 3	402	347	324	86.3	93.4
	§ 7	141	120	116	85.1	95.0
	§ 8	563	412	374	73.2	90.8
XX	4	470	349	322	74.3	92.3
XXII	3	168	74	61	44.0	82.4
Control	§ 1	740	708	642	95.7	90.7
	2	649	635	592	97.8	93.2
	§ 3	677	667	655	98.5	98.2
	4	333	320	214	96.1	66.9

§ . . . . The batch from which hatched out larvae were reared.

of sperm in their receptaculum seminis to fertilize the eggs. The latter were found only when the glass tubule methods were used, and especially in such examples which had been injected with a little quantity of seminal fluid as occasionally seen in the case employing the pupae to gather the semen.

In Table 1, series I is the first successful experiment made with the glass tubule. In series I and VII, the injected semen was taken from the bursae copulatrices of the female moths immediately after 30–180 minutes mating at 25°C. Nevertheless there is found a great difference between the percentage of success in the experiments. This might perhaps depend upon skill in practice. Comparing series II, III and IV, where the semen was taken from the bursae copulatrices as in series I, but the females had been isolated from the males for a different number of hours respectively, bad effects can be found on the rate of success due to the long isolation of the females.

Series VII and VIII show that there is little difference in the rate of success so far as the method of gathering seminal fluid is concerned, though practically the second method was more difficult. The poorer rate of success in series IX than in VIII may be due to the less amount of the seminal fluid in the pupae, and not to the character of the spermatozoa.

The 19 individuals used in series XX, XXI and XXII are all those upon which the artificial mating method was employed. Of these only in two cases did success attend the experiment. It should be noted that in these series four examples were gained with misformed spermatophore as shown in Fig. 3.

The table shows, as a whole, that practice increases the percentage of success and great skill may be expected to approximate it to that of the natural mating, and that it may not be difficult for any one to gain some 50 percent of success with glass tubule methods.

II. Effect on the number of eggs laid and on fertility

A remarkable difference was found in the number of eggs to a batch and in the fertility but scarcely any difference in the hatchability, between the experimented and controlled series. The former two characters, *i. e.* number and fertility of eggs show larger deviation and less value in the experimented series than in the controlled

TABLE 3.

Some characters of the offspring of artificially inseminized female moths.

Series of experiments	No. of batch	Reared larvae	Full grown larvae	Ratio full grown to reared (%)	Female[1]			Male[1]		
					Weight of a cocoon (gr.)	Weight of silk (gr.)	Ratio silk to cocoon (%)	Weight of a cocoon (gr.)	Weight of silk (gr.)	Ratio silk to cocoon (%)
VII	6	557	407	73.1	1.88	0.247	13.1	1.53	0 247	16.1
	11	100	90	90.0	2.18	0.321	14.7	1.71	0.294	17.2
VIII	2	283	232	82.0	2.16	0.300	13.9	1.66	0.265	16.0
	4	493	402	81.5	2.01	0.303	15.1	1.64	0.281	17.1
IX	3	298	233	79.9	2.13	0.304	14.3	1.73	0.286	16.5
	7	110	104	94.5	2.12	0.298	14.1	1.66	0.260	15.7
	8	303	283	93.4	1.97	0.285	14.5	1.53	0.265	17.3
Control	1	468	422	90.2	1.84	0.258	14.1	1.59	0.248	16.5
	3	606	438	72.3	1.91	0.280	14.7	1.63	0.262	17.1

1) Cocoon and silk weight show the average value of 20 individuals which were collected at random.

(Table 2). These results may be attributed to the physiological relation between copulation, spermatozoa, fertilization and oviposition, which may have been unfavourablly effected by the experiments. Details regarding these points will be discussed in another paper.

III. Effects on the progeny of the treated individuals

In order to study whether the spermatozoa had been influenced by the experiments, the progeny were bred. The result is shown in Table 3. In the table, the ratio of full grown larvae to reared represents viability; cocoon weight indicates indirectly the relative weight of the full grown larva; the ratio of silk weight to cocoon weight expresses roughly the silk producing ability of a larva. The data are not enough to warrant a definitive conclusion, but they enable one to believe that at least no unfavourable effect on the progeny results from the treatments. It is also notable that there is found no difference between the progeny of the spermatozoa taken from the moth and that from the pupa.

Consideration and conclusion

In 1916, as mentioned above, the first and only one success of artificial insemination in Lepidoptera was gained by HARRISON. His method is analogous to the present writer's artificial mating method. But the possibility of it is questionable, judging from the mechanism of the ejaculation in the silkworm moth. In fact, he made no other success than the one although he made repeated trials (FEDERLEY, 1929). It may not be unreasonable to suggest that the male of *Philosamia promethea,* which carried out the ejaculation in the operator's hands, had accidentally made a mating with a *promethea* female within a few minutes before the experiment and was in the state of imminent ejaculation.

In the silkworm moth, one might think of some other methods than those described above which might be successful: *e. g.,* to gather the spermatozoa either from the testis or from the receptaculum seminis of a mated female; or to inject the spermatozoa directly into the oviduct near the micropyle of the egg. Were these possible, they might contribute many valuable techniques in the

direction of the physiology of the fertilization and genetics, etc. But these methods can scarcely be put into practice. It is hardly possible to gather any sufficient quantity of mature spermatozoa directly from the testis, for those spermatozoa do not stay in the follicles of the testis but progress to the ductus deferens one by one, moreover the character of the spermatozoa in the testis is not the same as of those in the ductus deferens or the vesicula seminalis. It is also very difficult to gather sufficient spermatozoa from the receptaculum seminis to use in the experiment, on account of the minuteness of the organ. Furthermore it may be impossible to fertilize the eggs in the oviduct or ovarial tubes by direct injection of the spermatozoa, because of the delicacy and complexity of the mechanism of the penetration of the spermatozoa into the micropyle (ÔMURA. 1935) (6).

So it will be recognized that no successful method may be found for the artificial imsemination in the silkworm moth other than those described above.

However, it may not be impossible to modify the method. For example, it may be possible to mix the semen with such a solution as physiological salt solution or glucose solution to dilute the seminal fluid in order to make the injection easy, or to substitute some solution for the secretion of the glandula prostatica to activate the spermatozoa in the male sexual organs.

Each of the three methods above described possesses its own characteristics. The first glass tubule method needs healthy moths of both sexes, which have the ability to copulate, in order to gather the spermatozoa from the mated female, and it compels one to kill the female unless he makes the male to ejaculate outside the female body by early separation of the copulation. The second glass tubule method needs no female to get spermatozoa, and further, a feeble male, even the pupa, may be acceptable as the material as far as he can supply mature and sound spermatozoa. But it is the defect of this method that the male has to be killed. The artificial mating method needs healthy sexes and is most difficult in practice, beside consuming much time, yet it requires neither the sacrifice of one of the sexes nor the use of any instrument.

There is, however, a fundamental difference between the glass tubule and artificial mating method. In the latter method spermatozoa can be inseminized exactly as in the natural mating, while

in the former it is impossible; that is to say, in the former any kind of stimulus can be given to the spermatozoa at the operator's will, while in the latter it is impossible.

The operator may select either of the methods according to his circumstances.

In practice, either of the methods results equally without any unfavourable effect on the progeny, though the number of the eggs laid as well as the percentage of the fertilized eggs is reduced more or less. In conclusion, it may be stated that these methods can be applied to various biological experiments.

Résumé

1. The author has suggested three methods of artificial insemination of the silkworm moth.

2. The first is called the glass tubule method, in which the spermatozoa taken from the bursa copulatrix of a mated female were injected into that of a given female.

3. The second is also a glass tubule one, in which were used the spermatozoa taken from the ampulla ductus deferentis or vesicula seminalis of a male moth or pupa and activated by the secretion of the glandula prostatica.

4. The third is, so to speak, an artificial mating; which depends on the fact that the ejaculation of the male moth is caused by some 5 minutes mating, and not discontinued by early breaking of the copulation.

5. The treatments yielded some unfavourable effects on the total number of eggs laid as well as on their fertility, but not on the physiological characters of the progeny.

Literature cited

1. FEDERLEY, H. Methoden Zur Erforschung der Vererbung bei den Lepidopteren. Handb. der biol. Arbeitsmethoden. 290: 637–690. 1929.
2. HARRISON, J. W. H. Studies in the hybrid Bistoninae. Jour. of Genetics. 6: 95–161. 1916.
3. MACHIDA, J. and WATANABE, K. The relation between copulation and fertilization of *Bombyx mori*. Sangyô Sinpô. 406: 454–472. 1927. (in Japanese)
4. ÔMURA, S. A method of artificial insemination of *Bombyx mori*. Ôyô Dôbutugaku Zassi. 5: 281–285. 1933. (in Japanese)
5. ——. Other methods of artificial insemination of *Bombyx mori*. Ôyô Dôbutugaku Zassi. 7: 207–210. 1935. (in Japanese)
6. ——. The structure and functions of the male and female reproductive organs of *Bombyx mori*. Nippon Sansigaku Zassi. 6: 159–161. 1935. (Japanese résumé of lecture)
7. WATSON, L. R. Demonstration of instrumental insemination of queenbee. Jour. of Econ. Entomol. 20: 530–536. 1927.

STUDIES ON THE REPRODUCTIVE SYSTEM OF THE MALE OF *BOMBYX MORI*

I. STRUCTURE OF THE TESTIS AND THE INTRATESTICULAR BEHAVIOUR OF THE SPERMATOZOA

By

Seinosuke ÔMURA

Contents

I. Introduction 151
II. Material and Method 152
III. Structure of the Testis 153
IV. Intratesticular Behaviours of the Spermatozoa 159
1. Mechanism of the passing out of the spermatozoa from the lobulus testis to the ductulus efferens testis through the membrana basilaris 159
2. Activity of the spermatozoa in the testis 164
3. Experiments to ascertain the time when the full maturity of the spermatozoa is attained 166
V. Consideration and Discussion 169
1. Extent of the testis 169
2. Structure of the testis 170
3. Granular substance in the lobulus testis 172
4. Passing out of the spermatozoa and the function of the secretion of the ductulus efferens testis 173
5. Do the spermatozoa attain full maturity in the testis? .. 176
6. Break-up of the sperm bundle 177
VI. Conclusion 177
VII. Résumé 178
VIII. Literature 179
IX. Explanation of Plates 179

I. Introduction

Since the middle of the last century, many authors have described various forms of testis in insects. But most of the investigations were limited to the macroscopical features of the reproductive

[Jour. Facul. Agr. Hokkaido Imp. Univ. Sapporo, Vol. XXXVIII, Pt. 2, Oct. 1936]

organs. In the microscopical field, the works of CHOLODKOWSKY on Lepidopteran ('86) and Dipteran testes ('05) are representative ones. His works are those of extensive nature, and, for that reason, it is not possible for us to obtain a detailed knowledge of the insect testis.

However, within the last thirty years little addition has been made to the results of CHOLODKOWSKY's work on the structure of the testes in insects. During this period numerous papers on karyology and spermatogenesis have been published, but our knowledge of the minute structure of the testis remains little more than a blank. For this reason, little information is available concerning, for example, the nutrition of testis or the intratesticular behaviour of the spermatozoa. Occasionally opinions have been expressed on the former problem by ST. GEORGE ('98), GRÜNBERG ('03) and CHOLODKOWSKY ('05), all of whom recognized the "Apikalzelle" of *Bombyx mori* to be the source of nutrition in spermatogenesis, by CHOLODKOWSKY ('05) who found the "Nutrientzelle" in Dipteran testis. On the latter problem light has been thrown by PAYNE ('33), who discovered interesting facts concerning the movements of spermatozoa inside the Orthopteran testis, and by IKEDA ('13) who followed the course of the spermatozoa in *Bombyx mori* from the testis to the ductus deferens and found a special path for escape of the sperm in the membrane between the follicle and the ductulus efferens testis.

The writer's efforts were directed towards securing detailed knowledge of the histological structure of the testis and of the intratesticular behaviour of the spermatozoa.

For many valuable suggestions and criticism the writer is indebted to Prof. E. KAWAGUCHI, under whose guidance the work has been carried out. He is also indebted to Prof. T. INUKAI, who kindly read through the manuscript before publication and offered helpful criticism.

II. Material and Method

The material used in these investigations consisted of various races of *Bombyx mori* cultured in the Sericultural Laboratory of the Hokkaido Imperial University. The age of the pupa or imago was calculated under the normal temperature of about 25°C.

The development, after the fifth larval stage, varies in different races and sexes of the silkworm and is affected by the environmental conditions also. Of recent materials (male only) it is shown roughly as follows (in 25°C).

5th larval stage (up to the pupation)	11–12 days
Full grown	7–8th day
Beginning of the spinning	8–9th day
Pupal stage	12–14 days
Adult	5–8 days

The constructive age of the pupa, *e.g.*, five days before emergence etc., was calculated counting backward from the emergence day of the standard pupae which had been selected as a control at the same stage as the experimented pupae.

The estimation of the pupal or the imaginal age was important for this work. In this respect *Bombyx mori* proved to be a suitable material, because material of the same age could easily be procured.

Observations were made *in vitro* as well as upon sectioned preparations. CARNOY, BOUIN and CHAMPY's fluids were used as fixatives.

Experiments were undertaken employing the second glass tubule method of artificial insemination (*cf.* ÔMURA, '36).

III. Structure of the Testis

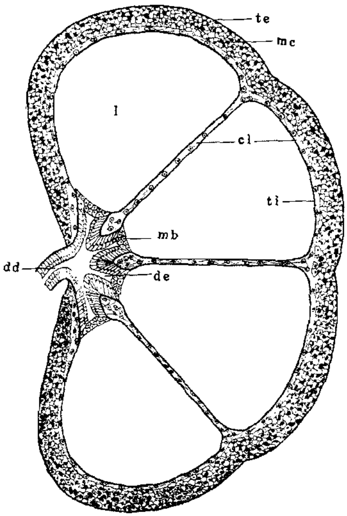
A pair of testes are situated in *Bombyx mori* on either side of the dorsal vessel in the fifth abdominal segment, without being united into a single mass as is the case in some species.

The testis is usually made up of four lobuli testis and ductuli efferentes testis. Each lobulus is bounded by the capsula lobuli and lined internally by the tunica interna, its opening into the ductulus efferens being closed by the membrana basilaris. The four lobuli and their ductuli are covered by the membrana communis and the tunica externa; thus constituting a testis (Text-Fig. 1). The former membrane stops short at the beginning of the ductus deferens (Figs. 8, 11), where the ductuli efferentes unite to form the ductus deferens.

In the pupal stage the lobuli swell out but during the larval stage they have a kidney-shape form. The size of a testis varies with the

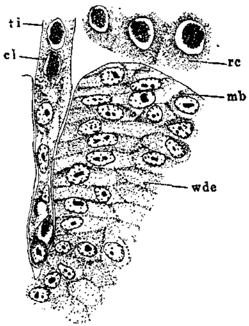
race of the worm and also with its age. The maximum size of a testis in a Chinese race of these worms measured on an average 3.94 mm in length, 2.05 mm in width and 1.9 mm in height.

The tunica externa is a very thin structureless membrane enveloping the testis (Fig. 1). It extends up to the ductus deferens beyond which it extends as its tunica propria (Fig. 11). The tunica externa is not a permanent covering because it breaks down during the pupal stage. Its break-down begins in a two day old pupal testis and becomes noticeable in a seven day old one; in the imaginal testis no tunica externa exists (Figs. 2–4).

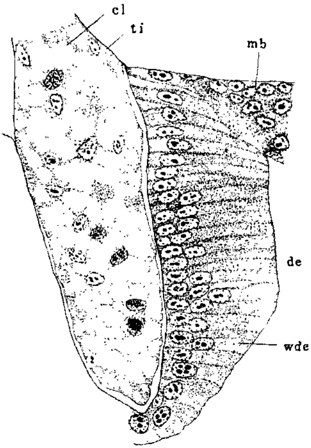


Text-Fig. 1. A schematic figure of testis of a full grown larva. cl...capsula lobuli, dd...ductus deferens, de...ductulus efferens testis, l...lobulus testis, mc...membrana communis, mb...membrana basilaris, te...tunica externa, ti...tunica interna. ca 30×.

The membrana communis lies just under the tunica externa and envelopes the whole testis. It is thick and made up of numerous cells, laden with fatty substances, which lie irregularly. The fatty substances contained in this layer were found to be abundant in the full grown larva, but diminished during the pupal stage (Figs. 1–3). In the adult testis the cells constituting the membrane are completely collapsed (Fig. 4).



Text-Fig. 2. Wall of ductulus efferens testis of 3 day old larva of 4th stage, cl...capsula lobuli, mb...membrana basilaris, rc... germ cell, ti...tunica interna, wde...wall of ductulus efferens. 1200×.



Text-Fig. 3. Wall of ductulus efferens testis of 3 day old larva of 5th stage. 1200×.

The capsula lobuli is the third layer in succession composed of connective tissue. It has three ramifications and divides the cavity of the testis into four lobuli (Text-Fig. 1, Fig. 8). The end of each ramification is wider, of which a cross section shows a deltaic shape (Figs. 8, 10, 11), and it also provides the basis for the wall of the ductulus efferens (Text-Figs. 2, 3. Figs. 8, 10, 11).

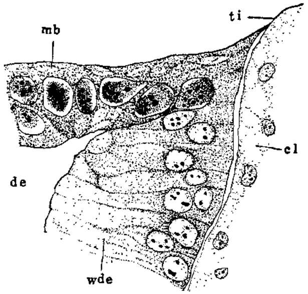
In the fully grown larval testis, numerous fatty granules are found everywhere inside the capsula lobuli which diminish as the

pupa advances in age and in correspondence with the reduction of the fatty substances in the cells of the membrana communis. In the imaginal testis there were found no such granules (Figs. 1–5).

The tunica interna is the innermost membrane. It lines the capsula lobuli, of course the deltaic part of it too, completely without a break. Its extremity envelopes the ductuli efferentes and finally unites with the tunica externa, being transformed into the tunica propria of the ductus deferens (Text-Fig. 1, Fig. 11).

The tunica interna is a thin structureless membrane like the tunica externa, but it is easily recognisable in cross sections. It is permanent and never breaks down in the adult (Fig. 4).

The membrana basilaris is the septum between each lobulus and its ductulus efferens. It is independent of the four membranes mentioned above, in its origin as well as function, but is closely related to the ductulus efferens.



Text-Fig. 4. Wall of ductulus efferens testis of 2 day old pupa. 1200×.

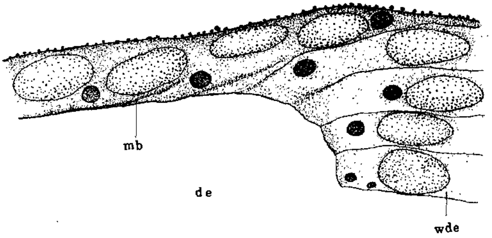
In larval testis, there was found no difference between the membrana basilaris and the ductulus efferens (Text-Figs. 2, 3, Fig. 8). But in a 2–3 day old pupa, a differentiation became noticeable between them: the nucleus of the former appearing to be degenerating with its chromatic substance coagulated, while in the latter no change

occurred (Text-Fig. 4, Fig. 10). In the testis of an eight day old pupa the nuclei of the cells of the membrana basilaris again assume normal appearance and the cells contain some secretory matter akin to that in the cells of the ductulus efferens (Text-Fig. 5). The reversionary process was however not followed.

The membrana basilaris becomes thinner and wider with advancing age and in an old pupa the cells are not disposed in a double layer (Figs. 12, 21, 22).

This membrane shows peculiar characteristics during the passage of the spermatozoa from the lobulus to the ductulus efferens (*v.* p. 161).

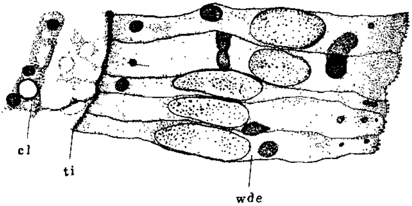
The ductulus efferens testis is the small duct belonging to each lobulus testis. The lumen of the ductulus, which is so narrow in the larval stage as to be hardly recognisable (Fig. 8), widens with age (Figs. 10–14, 22), and in the imaginal testis becomes very much wider. In the old adult (6–7 days old), in which nearly all of the spermatozoa have been discharged the junction of the four ductuli has large dimensions (Fig. 21). In such an adult testis, the ductuli become short and wide flattening out their walls parallel to the membrana basilaris.



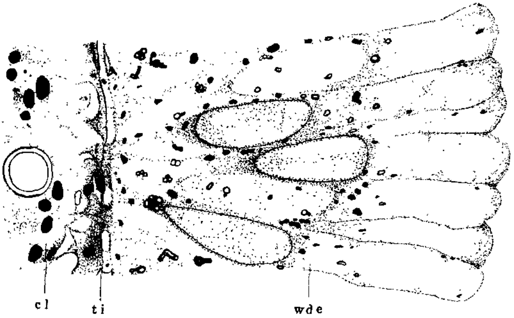
Text-Fig. 5. Wall of ductulus efferens testis of 8 day old pupa. 1200×.

The wall of the ductulus is made up of glandular cells, which increase in size during the successive pupal stages (Figs. 8, 10–12). The secretion of the cells begins 6–7 days before the emergence of the imago and reaches its maximum when the passage of the spermatozoa begins, *i. e.,* 3–4 days before the emergence, and then diminishes gradually (Text-Figs. 5–7). In a six day old adult, that

is just before the end of its life, little secretion was found inside these cells (Text-Fig. 8).



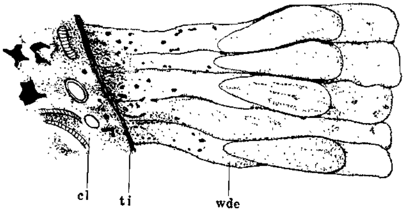
Text-Fig. 6. Wall of ductulus efferens testis of 9 day old pupa. 1200×.



Text-Fig. 7. Wall of ductulus efferens testis of pupa 1–2 days before emergence. 1200×.

On the whole, though the secretion in the cells of the ductulus efferens begins 2–3 days before the commencement of the passage of the spermatozoa (*cf.* p. 160), the rise and fall of the secretion corresponds roughly with the passage and discharge of the spermatozoa.

The source of the secretion seems to be the fatty substance contained in the capsula lobuli, on which the glandular cells stand. Text-Fig. 7, also Fig. 20, shows the close relation between them. The



Text-Fig. 8. Wall of ductulus efferens testis of 6 day old imago. 1200×.

function of the secretion will be dealt with at a later stage in this paper.

Numerous granules were found in the cavity of the lobuli of old pupae from whose capsula lobuli the fatty granules had disappeared (Figs. 12 and 22). Such granules were also found in the lobuli of the young pupa as well as of the full grown larva in whose capsula lobuli they are contained abundantly (Figs. 3, 6, 7). On the inner surface of the tunica interna also numerous such granules are found (Figs. 3, 5–7). Some of them may be those which have adhered to the tunica at the moment of fixation, but some are probably those just secreted through the tunica interna. The fatty reaction of this substance to osmic acid was negative. It is also notable that in 7 day old pupae, that is 6–7 days before the emergence of the imago, abundant fluid was found in the lobuli testis near the membrana basilaris (Fig. 9). It was not of fatty nature. Its origin as well as its relation to the secretion found in the membrana basilaris in young pupa is unknown to the writer (*cf.* Text-Fig. 5).

IV. Intratesticular Behaviours of the Spermatozoa

1. Mechanism of the passing out of the spermatozoa from the lobulus testis to the ductulus efferens testis through the membrana basilaris

The time of the passage of the spermatozoa from the lobulus testis to its ductulus efferens was determined by means of *in vitro* observation as well as by the study of sections. In the former

investigation, the existence of the spermatozoa in the ductus deferens was examined, because it is difficult to take out a ductulus efferens alone. The results are summarized in Table 1, where it is shown that the spermatozoa commenced coming out from the lobulus in the pre-imaginal stage: to be more precise, spermatozoa begin their exit in the pupae 3–4 days before the emergence of the imagos. The results obtained from sections confirm this view (Figs. 12, 14, Table 2).

TABLE 1.

Beginning of the translocation of the spermatozoa from the testis to the ductus deferens. (Observation *in vitro*).

Material: Kokusan-Si-101

Stage	Number of indvl's	Number of indvl's, in whose duct. def. there are found	
		sperm	no sperm
Pupa, 5 days before emergence	5	0	5
,, , 4 ,,	5	2	3
,, , 3 ,,	5	5	0
,, , 2 ,,	5	5	0

TABLE 2.

Beginning of the translocation of the spermatozoa from the lobulus to the ductulus efferens testis. (Observation in sections).

Material: Kokusan-Si-101

Stage	Number of indvl's	Number of indvl's, in whose ductul. eff. there are found	
		sperm	no speam
Pupa, 5 days before emergence	5	0	5
,, , 4 ,,	5	3	2
,, , 3 ,,	5	5	0

The mechanism of the escape of the spermatozoa into the ductulus efferens was investigated only from sections.

In a pupa, six days before emergence the spermatozoa lie scattered in the cavity of the lobuli testis in the form of bundles. In a two days older pupa (*i. e.*, four days before emergence) abundant sperm bundles with the heads of the spermatozoa turned towards the membrana basilaris are noticed (Fig. 12). The passage of the spermatozoa into the ductulus efferens is now imminent.

In a testis of a pupa a day older than the previous one, many sperm bundles are found to be passing out through the membrana basilaris (Fig. 14). These spermatozoa look as if they were hanging into the ductulus efferens from the membrane by their heads with tails streaming behind them (Figs. 13 and 16).

Such appearances are presented by the testes of subsequent stages also, although the number of sperm bundles declines with the age of the pupa. And even in a 6–7 day old imago, which is about to die, a few sperm bundles may be found passing out in this manner (Fig. 21).

No special pathway for the sperm bundles was found in the membrana basilairs. In the oldest imaginal testis, from which most of the spermatozoa had emerged and which contained very few sperm bundles, resulting in a significant shrinkage of the lobulus, perfect membranae basilares were found, though they had been stretched nearly to the fullest extent, and no pathway was found in any case. Fig. 21 shows one of such testes.

The question arises as to how the spermatozoa pass through the membrana basilaris, causing no rupture in its structure.

The figures in Plate II and III solve the question clearly.

In these figures, one can see the sperm bundles perforating respectively at many points on the membrana basilaris and slipping out through these into the ductulus efferens. One will notice a peculiarity on comparing Fig. 12 with Fig. 14; in that the direction of the head of the sperm bundle is quite opposite in the beginning and at the end of the passing out. The sperm bundles are in descending posture at the beginning of their emergence, with their heads turned towards the membrana basilaris, but in the end the tails of the spermatozoa slip out into the ductulus efferens, while the heads remain in the cavity of the lobulus. That is, the spermatozoa reverse their direction in the course of passing out.

The writer has traced the process of the reversion in a series of figures following. The sperm bundles which have collected at the membrana basilaris keep their heads close but not attached to it (Fig. 12). Then the tail is bent round 180° and over (Fig. 28). The bending extends to the anterior part, until at last the direction of the head is turned ('a' in Fig. 22). During that time the head scarcely changes position. That is, a bundle makes a vibration, the head playing the part of the centre. Thus in a moment of vibration the middle part of the tail takes the lead ('a' in Fig. 22). And, at last, the tail touches the membrana basilaris ('b' in Figs. 15, 16, 18, 19).

The tail of the spermatozoa must have no rigidity, therefore, though they tie up into bundles, it will be scarcely possible for them to perforate their own pathway through the membrane in such a manner as a person would stick a needle into cloth, no matter how tender the membrane may be.

The mechanism of the perforation was followed as shown in other figures. The part which at first reaches the membrana basilaris is not the tail end but the portion a little anterior to the end, as is suggested by Fig. 22 ('a'). In fact, the tail part makes an arc at the moment when it touches the membrane. Many of these figures are found in 'b' of Figs. 13, 15, 16, 18 and 19. The very elastic motion of the stretching moment of the arc will make the perforation through the cells of the membrana basilaris. 'b' in the figures indicated above shows the imminent stretching motion of the arc. The moment just next to it must be 'c' in Fig. 19, at which a part of the tail is pushed out keeping the bending posture, and followed up by the successive postures in Fig. 16 ('d'), 17 ('e'), 18 ('f') and 19 ('g'). The moment when the arc is stretched is shown in Fig. 23. Therefore, the part which slips out first is not the tail end, but a point slightly anterior to it. In fact, the writer has neither found a tail part which has slipped out into the ductulus efferens in a stretched form shorter than that as seen in Fig. 23, nor has he caught any figure showing that only the tail end had just slipped out.

Apyrene spermatozoa were generally not found outside the testes, but an exceptional case was met with in which an ampulla ductus deferentis contained a mass of the apyrene spermatozoa and residue of the sheaths of the sperm bundles (Fig. 25). A view of an escaping apyrene sperm bundle was caught in Fig. 24.

As regards the sheath of the sperm bundle, the following facts were observed. The sperm bundles lying inside the lobulus have a complete sheath (Fig. 28), but those that are lying in the ductulus efferens do not possess it (Fig. 16). (Some sperm bundles found on the *inner side* of the membrana basilaris of Figs. 15–19 appear to have no sheath, owing to the pellucidity of the sheath. In general the sheath is recognized by its nuclei). On the inner side of the membrana basilaris the sheaths accumulate as more and more of the spermatozoa slip out of it (Fig. 16). These three figures lead one to suggest that the sheath is cast off in the course of the passing out of the spermatozoa through the membrana basilaris.

The process of the casting off of the sheath was traced as follows. Fig. 23 shows a sperm bundle, of which a part has slipped out without the sheath, while a part remains inside the lobulus covered with the sheath, which has a somewhat shrunken shape having been partially thrust back towards the head. As the spermatozoa escape out, the sheath shrinks until it is no more than a structureless mass (Figs. 24 and 27). The casting off of the sheath begins at the tail end of the spermatozoa and extends up to its head. The cast off sheaths are left behind inside the lobulus on the membrana basilaris. Fig. 26 shows the sheath enveloping the sperm bundles and also cast off sheaths in which no spermatozoa can be detected.

The position where the perforation is made, that is whether in the cytoplasm or on the boundary of cells, could not be determined accurately in the present work. That no nucleus is ever affected by the passage of the spermatozoa is clear from Figs. 15 and 23.

The fate of the foramina could not be clearly ascertained. But the writer supposes from Figs. 16, 24 and 27 that they may be plugged or covered with the sheaths which have been left behind after the escape of the sperm bundles.

As mentioned above, spermatozoa begin to pass out of the testis in the advanced pupal stage and continue to do so till the death of the individual. But during that time the formation of the spermatozoa does not accompany the process. Thus the contents of the testis diminish with age, resulting in the reduction of the size of it.

The writer has measured the testis by weight. As it is hard to gain the real weight accurately *in vitro* because of the difficulty in removing the lymph from the testis surface, the relative weights were measured after a fixation during thirty minutes by CARNOY's

fixative. Results are summarized in Table 3. There it is shown that the ratio of the weight of the testis of the pupa four days before emergence (of which no spermatozoa has passed out) to that of the moth just emerged to that of the one four days old is 100: 53: 15. In the testis of a four day old moth, there are found few normal spermatozoa so that its value expresses roughly the relative weight of the testis alone. Consequently the ratio of the sperm quantity contained in the above three testes is shown roughly as (100–15): (53–15): (15–15)≒85: 38: 1. That is to say, the majority of the spermatozoa have already slipped out when the moth emerges. Also it is shown that copulation has no connection with the speed of the passing out of the spermatozoa.

TABLE 3.

Weight of the testis.[1]

Material: a hybrid between a Japanese univoltine and a Chinese bivoltine race.

Stage of the individuals	Date	No. of testes	Weight (gr.)	Weight per testis (gr.)	Ratio	Remark
Pupa, 4 days before emergence	24/X, '34	20	0.212	0.0106	100	
,, , 1 day ,,	27/X, ,,	20	0.178	0.0089	83	
Moth, 1 day old	28/X, ,,	20	0.112	0.0056	53	non-mated
,, , 2 days old	29/X, ,,	20	0.076	0.0038	36	,,
,, , 3 days old	30/X, ,,	20	0.062	0.0031	29	,,
,, , 3 days old	,,	20	0.059	0.0030	28	mated 40 minutes on 29/X
,, , 4 days old	3/XI, ,,	20	0.031	0.0016	15	non-mated

1) The weighing was done after 30 minutes fixation by CARNOY's fluid.

2. Activity of the spermatozoa in the testis

The above mentioned facts enable us to conclude that the passing out of the spermatozoa is due to their own movements and not to any other agency. It seems, therefore, doubtless that the spermatozoa are active at least during the course of the passing out.

Hence the writer has attempted to trace the time of the beginning of the movement and to catch the moment of the end of it. For this

purpose spermatozoa in the testis of different stages were observed *in vitro*. The results are summarized in Table 4. There was found no motile spermatozoon in the testis of young pupae, but some motile ones were found in the old pupal testis where the passing out is about to take place. They showed a weak, yet distinct vibratile movement of the tail.

TABLE 4.

The activity of the spermatozoa in the lobulus testis of different stages.

Stage	No. of indvl's	No. of indvl's, whose spermatozoa are		
		—	+	++
Full grown larva	10	10	0	0
2 day old pupa	10	10	0	0
6 day old pupa	10	10	0	0
10 day old pupa (*4 days before emergence*)	10	4	6	0

—....no motile spermatozoa, +....several motile spermatozoa per field, ++....many motile spermatozoa per field.

Next, the fate of the activity which is shown in the course of the passing out was studied. In sectioned preparations the spermatozoa which had passed out into the ductulus efferens no longer appear active but take a quiescent attitude (Fig. 22), contrary to the violently active appearance of the ones passing out through the membrana basilaris (Figs. 13, 14).

Examination was pursued *in vitro*, employing the spermatozoa taken from the ductus deferens nearest to the testis, because it was scarcely possible to gather them only from the ductulus efferens without the inclusion of any from another part. These spermatozoa also have shown no activity.

These facts indicate that the spermatozoa must have been inactivated in their course from the membrana basilaris to the ductus deferens. Probably, the activity is lost when they slip out into the ductulus efferens.

The above data justify the supposition that spermatozoa gain activity just before the beginning of the passing out, presumably, at the

start of their gathering at the membrana basilaris, and that they lose it when their whole body has passed out into the ductulus efferens.

3. Experiments to ascertain the time when the full maturity of the spermatozoa is attained

To ascertain when the full maturity of the spermatozoa is attained, certain experiments were made (Table 5).

TABLE 5.

Experiments concerned with the character of the spermatozoa in testis.

No. of exp.	No. of indvl's.	Spermatozoa researched	Method of experiment	Result
1a	10	Taken from lobuli of pupa 4 days before emergence	Observation of the activity of spermatozoa	Some spermatozoa moved gently
1b	10	Taken from duct. def. of pupa 1 day before emergence	,,	No spermatozoa moved
2a	10	Taken from lobuli of pupa 4 days before emergence	Reaction of spermatozoa to the secretion of gl. prostatica	Negative
2b	10	Taken from prox. part of duct. def. of pupa 2 days before emergence	,,	Positive
2c	10	Taken from middle part of duct. def. of the same pupa employed in 2b	,,	,,
2d	10	Taken from amp. duct. def. of the same pupa employed in 2b	,,	,,
3a	10	Taken from lobuli of pupa 4 days before emergence	Reaction of spermatozoa to the liquid in burs. cop. of the female 2 days after a mating	Negative
3b	10	Taken from duct. def. of pupa 3 days before emergence	,,	Positive
4a	20	Taken from lobuli of pupa 4 days before emergence	Art. insemination by the 2nd glass tubule method	No females were fertilized
4b	4	Taken from amp. duct. def. of moth a day old	,,	2 females were fertilized

First, the activity of the spermatozoa was examined by observing the ones taken from the lobuli testium of old pupae of four days before emergence, and from the ductus deferentes of pupae of the day before emergence. Some of the former showed gentle activity, while the latter showed none at all (Table 4, Table 5, '1a, 1b').

Second, the reaction of the spermatozoa to the secretion of the *glandula prostatica*[1] *of a fresh moth* was examined. Since the sperm bundle in the lobulus is enveloped in a sheath, it was necessary to break the sheath in order to cause the spermatozoa to make contact directly with the secretion of the glandula prostatica. In practice, some of the bundles had lost the sheath in the course of the preparation *in vitro*, probably by the pressure of the cover glass, and these spermatozoa were examined for their activity. But no tendency was found for them to be activated by the secretion. On the contrary, the spermatozoa taken from the ductus deferens all became violently active at the moment when they came into contact with the secretion. In this case there was no difference of the activity in comparison with the spermatozoa which were taken from a different part of the ductus deferens. The spermatozoa taken from the part nearest to the testis showed the same violent activity as those from the most distal part, *i. e.*, from the ampulla ductus deferentis (Table 5, '2a, 2b, 2c').

The above two experiments suggest that the character of the spermatozoa differs in the lobulus testis and in the ductus deferens. Therefore, it is recognized that the spermatozoa are subjected to some influences in their course from the lobulus testis to the ductus deferens but to none in the ductus deferens.

But the second experiment could not determine whether the *non-susceptibility of the spermatozoa in* the *lobulus testis to* the secretion of the glandula prostatica is due to their inherent character or to their having not all been supplied with the secretion that had been supplied to those of the ductus deferens. In fact, the spermatozoa in the lobulus testis have received no influence of the secretion of the ductulus efferens at least. The third experiment was made, therefore, intending to keep the spermatozoa from both the

---

1). The glandula prostatica is a gland included in the male sexual system. The function of the secretion from it is activation of the spermatozoa in the post-testicular male sexual organs. The details will be found in the succeeding paper.

ductus deferens and from the lobulus testis under as nearly as possible similar conditions.

Third, the liquid contained in the bursa copulatrix of the female moth two days after copulation was applied to the spermatozoa from the lobulus testis. This liquid consisted of every secretion of the male sexual organs and so small a number of spermatozoa as not to disturb the examination of the character of those to which the liquid had been added, for most of the spermatozoa ejaculated into the bursa copulatrix had been translocated to the receptaculum seminis. So that, if the spermatozoa in the lobulus testis had the same character as those in the ductus deferens they should show the same reaction as that of the latter ones. But the result was the same as that of the second experiment (Table 5, '3a, 3b').

The last experiment was made in order to research the fertilizing ability of these spermatozoa. They were injected artificially into the bursae copulatrices of virgin females with the secretion of the glandula prostatica by the second glass tubule method of artificial insemination.

Of the twenty females who were injected with the semen containing some active spermatozoa taken from the lobuli testium of the pupae four days before emergence, sixteen individuals received the semen in their bursae copulatrices. But none of them had spermatozoa in their receptaculi seminis, probably since these did not have the ability to progress there (Table 5, '4a', Table 6, '4a').

TABLE 6.

Results of the artificial insemination employing intratesticular and post-testicular spermatozoa by the second glass tubule method.

Material: a hybrid of a Chinese and a Japanese race.

No. of exp.	Employed sperm	Indvl's. experimented	Indvl's. received semen	Indvl's. fertilized	Fertility
4a	Taken from lobuli of pupa 4 days before emergence	20	16	0	—
4b	Taken from amp. duct. def. of 1 day old moth	4	4	2	$\frac{24}{291}, \frac{52}{135}$ (8.2%, 39.3%)

In the ductus deferens, at the proximal part, there were found too few spermatozoa to use in the artificial insemination, therefore, some in the ampullae ductum deferentium were used, for they have the same character as those in the proximal part. All of the four females who were injected with the sperm from the ductus deferentes received the semen in their bursae copulatrices, and two of them were fertilized (Table 5, '4b', Table 6, '4b'). In this case the fertility was very low. This is probably due to the lesser quantity of the sperm than is received in natural copulation, but not to the character of the spermatozoa. For, the spermatozoa of *Bombyx mori* are considered to receive no aging influence in the post-testicular male organs[1).

This experiment proved that the spermatozoa in the lobulus testis do not possess fertilizing ability, while those in the ductus deferens have it.

V. Consideration and Discussion

1. *Extent of the testis*

The present writer has determined the extent of the testis in the region covered by the membrana communis. No precise description was made as to the extent of the testis either by CHOLODKOWSKY, who has studied the testis of insects minutely, or by IKEDA who has researched the construction of the testis of *Bombyx mori.* The present writer's view on this point is based on the following reasoning.

The testis of *Bombyx mori* is not divided into lobuli in the embryological stage of the creature. The ramification of the capsula lobuli begins in the 2–3 day old larva (TOYAMA, '94). A little later the membranae basilares and the ductuli efferentes are formed by the cells, which differ from the spermatogonia and are scattered in the testis (GRÜNBERG, '03). Both the membrana basilaris and the ductulus efferens should be, therefore, included in one region, either in the testis or in the ductus deferens or in a special region.

The membrana communis covers the lobuli testis, membranae basilares and ductuli efferentes, drawing a clear boundary to the

1). The details will be given in the succeeding paper.

ductus deferens. The ductuli efferentes have close relation to the capsula lobuli (*cf.* p. 155), to which the ductus deferens has no relation. Consequently, if no special category is assigned for the membrana basilaris and the ductulus efferens, it will be rather natural to include them in the region of the testis. In the research on the character or behaviour of the spermatozoa, it was not inconvenient to regard a lobulus and a ductulus efferens as a combined organ and not as separated organs. Thus, the present writer has included the membrana basilaris and the ductulus efferens in the region of the testis, giving no special name to them.

2. Structure of the testis

The tunica externa has been described first in Lepidoptera by CHOLODKOWSKY ('86)[1] as "tracheale Hülle". It was considered by him as being made up of transformed tracheae. But no tracheal constitution was found on it by the present writer. It will be more natural to look upon it as the transformed margin of the membrana communis. Its function may be the protection of the membrana communis. This view may be supported by the fact that the breaking down of the tunica externa accompanies the decline of the excretion of the granules from the membrana communis.

The membrana communis has been described as "Fettkörperschicht" by CHOLODKOWSKY ('86), who found the fatty granules in it, and as "Kyôtû-Himaku" (common membrane) by IKEDA ('13). The present writer has chosen the latter name, simply owing to his intention to base the nomenclature not upon the physiological character but upon the morphological one. No particular description has ever been made of the cells of this membrane. Further, the writer's observation has not been sufficient to warrant a conclusive statement on its function, whether it is nothing but the storage of fatty substance or whether it has assimilating and dissimilating ability. But it is notable that this membrane has a very similar appearance to the fat body. The writer considers this membrane as a source of the nutrients of the testis (*cf.* p. 173).

The capsula lobuli is called "Seinô-Himaku" (follicle membrane) by IKEDA, "chitinöse Hülle" by CHOLODKOWSKY, who believed it to

1). The original paper was not at hand, and the résumé was read in his other paper ('05).

have a chitinous character. No discussion will be demanded to deny this view. This membrane consists of connective tissue. The fatty granules herein found may not be found to be the secretion of the cells constituting this membrane, but the substance permeated from the membrana communis. Thus, this membrane may play the rôle of a canal which transports the granules.

The colour of the testis, which is found in some species of Lepidoptera, is said to be due to the granules contained in this membrane (CHOLODKOWSKY, '86). The relation between the granules found by the present writer and the colouring granules could not be made clear, as the testis of *Bombyx mori* has no other colouration than that of the haemolymph. (Further description of the membrane is found on p. 173).

The tunica interna is called "membrana propria" by CHOLODKOWSKY. It may be the transformed margin of the adjoining membrane similar to the tunica externa, serving to protect the capsula lobuli.

CHOLODKOWSKY ('05) has stated after his studies on Lepidopteran and Dipteran testis that even in a family all species do not always have the same constitution of testis, and some of them want one of the membranes. But his view may not be fully warranted, as his results are obtained from a few specimens of various species. Each membrane varies in appearance with the age of the individuals, as shown by the present writer. Therefore, CHOLODKOWSKY's view will need further proof from the observation of many specimens of various ages in each species.

The existence of the trachea in the lobulus testis is demonstrated by old authors (VERSON, '96, TICHOMIROW, '98), and supported by the present writer's observation (Fig. 21). But CHOLODKOWSKY strongly insisted upon the absence of it ('05). It seems strange that there should be such differences in these easy observations.

It was demonstrated by the present writer that the size of the testis varies remarkably with the age of the individual. The investigations treating the size of insect testis—recently some of these investigations have been pursued in *Drosophila*, *e. g.*, by DOBZHANSKY and STURTEVANT ('36)—will require full attention to this point.

The membrana basilaris is very unusual in its character. It has the same origin as the ductulus efferens. In a three day old pupa, its differentiation to the membrane begins, with the coagula-

tion of the chromatin of the nucleus. But a few days later the coagulation is not found and the cell contains a vacuole enclosing a similar substance to that in the vacuoles of the cells of the ductulus efferens which has just developed as a gland and begun secretion.

Until the spermatozoa mature, the membrana basilaris plays the rôle of a partition wall between the lobulus and the ductulus efferens, but in old pupal stage when the spermatozoa have grown fully, it becomes a unique sort of screen which lets the spermatozoa pass out and through by the movement of the spermatozoa themselves. It is so tender as to be perforated by the tail of the sperm bundle, but so tough as not be torn by the numerous perforations by the sperm bundles.

MACHIDA ('29 b) has shown that a testis of *Bombyx mori* contains some 3000–4000 bundles of sound spermatozoa, that is, 800–1000 bundles per lobulus. Therefore, 800–1000 perforations, which have nearly the same size as the nucleus of the membrane cell, cannot tear this membrane. If it be assumed that the membrane makes a circle, of which the diameter consists of thirty cells—in actual fact, some thirty cells are numbered in the cross section of the membrane—then the number of the cells constituting the membrane may be calculated roughly as follows; $\pi \times 15^2 = 706$. That is, approximately one perforation is made in each cell and yet does not break the membrane.

On the structure of the ductulus efferens, there has been no study hitherto, just as in the case of the membrana basilaris. The present writer has revealed its glandular constitution and researched the stage of its secretion. Further, on the function of the secretion, an inference has been made (*v*. p. 175).

3. Granular substance in the lobulus testis

Hitherto, scarcely any attention has been paid to the granular substance in the lobulus. Though the present writer made no researches upon the stage when it comes out into the lobulus nor studies of its origin, he has found that the substance appears abundant at the full grown larva and diminishes in the imago. The disappearance of the granules in the capsula lobuli, the appearance of the granules of the lobulus of having been secreted from the capsula lobuli and the close relation of the period of existence of both kinds

of granules in the capsula lobuli and in the lobulus causes one to regard them to have intimate relation, though they differ in character, as the former indicates fatty reaction while the latter does not. If the granules of the lobulus have their origin in the fatty substance of the capsula lobuli, then the capsula lobuli must have some function to change the character of the granules which come out from the membrana communis. The coloured granules in the capsula lobuli of some species of Lepidoptera such as are never found in the membrana communis have given a suggestion to the above supposition, for the creation of these granules must be a function of the capsula lobuli. It is to be regretted that the data gained by the present writer are not enough to warrant a conclusion on this point.

GRÜNGERG ('03) regarded the "Apikalzelle" as the source of the nutrition of the spermatogenesis and stated that they have assimilating and dissimilating ability, though no details on the nutritive substance were given. CHOLODKOWSKY ('05) described the "Nahrungszelle" in a Dipteran testis, but he gave no data to indicate its function. He also found large granules transmitting themselves from the capsula lobuli to the lobulus in a species of Diptera, but he stated nothing either on their function or on their character. The present writer has no data for a criticism of these opinions, but at least in *Bombyx mori* there was found neither the "Nahrungszelle" nor the "large granules". Further, the "Apikalzelle" has been regarded as becoming functionless in full grown larval stage or early pupal stage (GRÜNBERG ('03)). In the pupal stage, accordingly, there is considered to be no nutritive substance other than the haemolymph and the granules found in the lobulus.

The stage when the granules are found abundantly in the lobulus coincides with the stage when the spermatogenesis enters the latter half of its course when much nutrient will be needed. The present writer considers that these granules serve as a nutrient of the testis, and because they are found in the pupal testis in which most of the spermatozoa have nearly finished maturing, that a part of them are employed as energy sources consumable by mature spermatozoa.

4. Passing out of the spermatozoa and the function of the secretion of the ductulus efferens testis

In Orthoptera, PAYNE ('33) has made an interesting observation *in vitro* on the getting out of the spermatozoa from testis. He has

discovered the fact that the spermatozoa move rather regularly within the follicle of the testis ascending, crossing and descending, then get out into the ductus deferens. PAYNE's observation was mainly directed to the movement of the spermatozoa and no notion is given on the mechanism of the getting out of the spermatozoa from the follicle into the ductus deferens nor even on the presence or absence of a membrane analogous to the membrana basilaris of *Bombyx mori*. IKEDA ('13) has observed the mechanism of the getting out of the spermatozoa in *Bombyx mori* using fixed preparations, and come to the conclusion that spermatozoa flow out from the lobulus through a pathway which appears naturally at some certain position in the membrana basilaris.

The particular mechanism of the passing out of the spermatozoa from the lobulus has been described above in the present paper. It denies the theory of IKEDA.

Whether this is a common mechanism occurring in all insect testes or only in Lepidoptera, is not yet determined.

The main process of the mechanism has been cleared fully, but a few questions are left, which need some consideration.

How do the spermatozoa gather toward the membrana basilaris? PAYNE has explained it by the assertion that the descending posture is due to the function of gravity. But he neither examined the geotaxis of the sperm bundles nor determined the natural position of the follicle. In *Bombyx mori*, though it is unknown what direction is taken by the testis in natural position; no matter in what posture the pupa was placed, no effect was noted on the passing out of the spermatozoa. Therefore, gravity has no effect on the descending posture of the sperm bundles.

MACHIDA ('29a) has stated that in an old pupa the apyrene spermatozoa dissolve in the basal portion of the lobulus, probably due to the character of the haemolymph, which has changed only in the basal part of the follicle under some unknown influence. The present writer supposes that this change of the character of the haemolymph may be due to the substance found near the membrana basilaris shortly before the time when spermatozoa begin to gather towards the membrane, and that this substance attracts the spermatozoa to the membrane by chemotaxis. Although the origin and character of this substance could not be determined, the stage of the appearance of it has led him to make such a supposition. The relation between

this substance and the secreted spheres found in the cytoplasm of the membrana basilaris could not be cleared up.

Other questions arise as to the perforation by the spermatozoa: where it occurs, whether on the boundary of cells or in the cytoplasm, or whether the position is determined to each cell; also whether each bundle makes its own foramen respectively, or whether multiple passing out is allowed through one foramen. It is to be regretted that the present data make no contribution to these problems.

MACHIDA ('29a) stated that apyrene spermatozoa are dissolved in the testis and are never found in the post-testicular organs. The present work also suggests that it is too complicated for the apyrene spermatozoa, which have irregular shape and size and probably have no activity, to pass through the membrana basilaris. In fact, in this work generally no apyrene spermatozoon was found in the post-testicular organs. But one exceptional case was found at the membrana basilaris. That case may not have been caused by the activity of the apyrene spermatozoa themselves but accidentally by the eupyrene spermatozoa, which had pushed out the former by chance. But the other exception, in which a mass of apyrene spermatozoa and the residue of the cystmembranes was found among the spermatozoa in the ampulla ductus deferentis, cannot be explained by the above assertion. Perhaps it has flowed out through a breakage of the membrana basilaris, which might be accidentally made in the course of the passing out of the spermatozoa. Therefore, it cannot be concluded that the membrana basilaris may not be absolutely broken by the perforations of the sperm bundles.

Since the spermatozoa pass out through the membrana basilaris in such a complex manner as mentioned above and some active spermatozoa are found *in vitro*, they must have activity at least during the course of their passing out. Further, it was proved *in vitro* that the spermatozoa are motionless in the most proximal part of the ductus deferens. Therefore, the spermatozoa will gain activity probably when they begin the descending movement and lose it when they have passed out into the ductulus efferens. These facts suggest that the secretion of the ductulus efferens has some function to negative the activity of the spermatozoa.

In addition, it may be well to assume the possibility of the presence of a motor centre in the spermatozoon from the view point of the mechanism of the passing out. If it is an established fact

that the secretion of the ductulus efferens has the above fu spermatozoa cannot slip out from the lobulus unless having a centre in their head or middle piece, because, if the centre w *the tail part, the spermatozoa would lose activity in the co* the passing out as soon as the tail has pushed out into the du efferens which is surely filled with the secretion. Therefor tail-preceding-progression of the spermatozoa may be a nec condition for the completion of the slipping out, protecting th or middle piece, where the motor centre is located, from the thetic solution.

5. Do the spermatozoa attain full maturity in the testis?

In the former paper (ÔMURA, '36) the writer has noted t the artificial insemination, there was found no difference i character of the offspring of the spermatozoa of pupa and i This furnishes a datum to support the opinon that the sperm are subject to no maturing influence in the post-testicular o One of the present experiments has shown that the spermatozo different levels of the ductus deferens have the same reaction *secretion of the glandula* prostatica. *This shows that the sperm* in the proximal part of the ductus deferens have the same cha as those in the ampulla. Another experiment has shown th spermatozoa do not have fertilizing ability in the lobulus but it in the ductus deferens.

These results indicate that the spermatozoa attain full ma not in the lobulus but in the proximal part of the ductus def and justify the inference that the completion of the maturing take place either while the spermatozoa are passing out throu membrana basilaris or while on their way through the du efferens or in both of the courses. To ascertain this point an at was made to add the secretion of the ductulus efferens to the sp tozoa in the lobulus. The result was negative. But it is not known whether or not the function of the secretion is a nec condition for the full maturity. It will be concluded, howeve the function of the secretion of the ductulus efferens is not ficient condition for the attainment of full maturity, and th *full maturity cannot be attained unless the spermatozoa pa* through the membrana basilaris. The particular movement

spermatozoa in the strange secretion near the membrana basilaris accompanying the casting off of the sheath of the bundle must be a necessary condition for the accomplishment of maturity. The full maturity of the spermatozoa may depend, perhaps, upon a change in their colloïdal state or upon a transformation of their protoplasm.

6. Break-up of the sperm bundle

Judging from the figure of the shrinkage of the sheath in the course of the passing out, the sheath may stick to the sperm bundle only at the top of the head, enveloping the other portion and keeping the spermatozoa in a bundle, but so that they can dishevel their tails in the bundle.

In *Bombyx mori,* as indicated by IKEDA ('13), in the case of some of the spermatozoa which have passed out from the testis, the bundle is dissolved while in others the bundle is kept. Such a dissolution of the bundle appears to occur by chance. This may perhaps be due, the present writer infers, to the manner of the unclothing of the sheath; when the adhered part of the sheath is not taken off at all, the bundle may not disintegrate; when no sheath adheres to the head, all individual spermatozoa separate from the bundle; when a part of it is cast away, some of them fall apart from the bundle.

PAYNE stated that in *Chortophaga* the sperm bundle has a hyaline cap and the bundle is dissolved in the female sexual organ, owing to the dissolution of the hyaline cap by the action of an enzyme. But in *Bombyx mori* the bundles are broken when they are touched by the secretion of the glandula prostatica. This may not be owing to the action of the enzyme but to the result of the movement of the spermatozoa which is brought about by the secretion. The individual movement of the spermatozoa may break the bundle mechanically.

VI. Conclusion

The testis consists of four sets of lobuli testis and ductuli efferentes testis, which are enveloped in the tunica externa and the membrana communis. Each lobulus is covered with the capsula lobuli and lined with the tunica interna. A lobulus is partitioned from its ductulus efferens by the membrana basilaris.

The fatty substance found in the membrana communis is secreted out into the capsula lobuli and is transported through it.

A granular substance was found in the lobulus. There were found some data to lead to the inference that it has its origin in the fatty granules in the capsula lobuli and that it serves as a nutrient of the spermatogenesis.

The ductulus efferens was revealed to consist of glandular cells, of which the secretion seems to have a function to inactivate the activity of the spermatozoa.

In the lobulus the spermatozoa group in bundles. Each bundle passes out into the ductulus efferens through the membrana basilaris in a particular and complex manner each perforating its own pathway by its own action.

In the course of the passing out, the sheath of the bundle is cast away and left in the lobulus covering each foramen.

The passing out of the spermatozoa begins in the old pupal stage 3–4 days before emergence, and the majority of the spermatozoa translocate into the post-testicular organs in the pupal stage.

No formation of new spermatozoa in the lobulus accompanies this translocation, consequently the testis is reduced in size with age.

Spermatozoa gain activity only in the course of the passing out.

The motor centre of the spermatozoa was inferred to be in their head or middle piece from the mechanism of the passing out and the function of the secretion of the ductulus efferens.

The full maturity of the spermatozoa is attained during the passage of the spermatozoa from the lobulus to the ductus deferens, that is, in the testis.

VII. Résumé

1. The construction of the testis was studied histologically and the function of each constituent part of the testis was researched.

2. *A definition of the extent of the testis was given.*

3. The source of the granular substance found in the lobulus was considered, and its function was discussed.

4. The intratesticular behaviour of the spermatozoa was studied, especially the characteristic manner of the passing out through the membrana basilaris was fully observed.

5. An experimental investigation was made on the attainment of full maturity of the spermatozoa.

VIII. Literature

The literature marked* was not actually accessible to the writer.

*1. CHOLODKOWSKY, N., Der männliche Geschlechtsapparat der Lepidopteren, *eine vergleichend-anatomische Untersuchung*. *Denkschriften* (SAPISKI) der Kais. Akad. Wiss. St. Petersburg. 52, Nr. 4. 1886. (in Russian).

2. ——., Ueber den Bau des Dipterenhodens. Zeits. wiss. Zool. 82, 389–410. 1905.

3. DOBZHANSKY, TH. and A. H. STURTEVANT, Further data on maternal effects in *Drosophila pseudoöbscura*. Proc. Nat. Acad. Sci. U. S. A. 21, 566–570. 1936.

4. GRÜNBERG, K., Untersuchungen über die Keim- und Nährzellen in den Hoden und Ovarien der Lepidopteren. Ein Beitrag zur Kenntnis der Entwicklung und Ausbildung der Keimdrüsen bei den Insekten. Zeits. wiss. Zool. 74, 327–395. 1903.

5. IKEDA, E., Anatomical and physiological researches on the silk worm. Tôkyô. 1913. (in Japanese).

6. MACHIDA, J., Eine experimentelle Untersuchung über die apyrenen Spermatozoen des Seidenspinners *Bombyx mori L.* Zeits. Zellf. u. mik. Anat. 9, 466–510. 1929a.

7. ——., The number of the spermatozoa of *Bombyx mori*. Ôyô-Dôbutugaku-Zassi. 1, 9–13. 1929b. (in Japanese).

8. ÔMURA, S., Artificial insemination of *Bombyx mori*. Jour Facul. Agric., Hokkaido Imp. Univ. 38, 135–150. 1936.

9. PAYNE, M. A., The structure of the testis and movement of sperms in *Chortophaga viridifasciata* as demonstrated by intravitam technique. Jour. Morph. 54, 321–346. 1933.

10. TICHOMIROW, A., Zur Anatomie des Insektenhodens. Zool. Anz. 21, 623–630. 1898.

11. TOYAMA, K., On the spermatogenesis of the silk worm. Bull. Agric. Coll. Tôkyô. Imp. Univ. 2, 125–157. 1894.

*12. VALETTE ST. GEORGE, A. V. LA, Zur Samen- und Eibildung beim Seidenspinner. Arch. f. mikr. Anat. 50, 1898.

*13. VERSON, E., La spermatogenesi nel *Bombyx mori*. R. Staz. Bacolog. Sper. Padova. 3, 1889.

IX. Explanation of Plates

Abbreviations

a, b, c, d, e, f, g .... progressive stages in the course of the passing out of spermatozoa.

ap	....	apyrene sperm bundle.
cl	....	capsula lobuli.
de	....	ductulus efferens testis.
mb	....	membrana basilaris.
mc	....	membrana communis.
sh	....	sheath of sperm bundle.
sh_1	....	cross section of sperm bundle with sheath.
sh_2	....	cast off sheath of sperm bundle.
ti	....	tunica interna.

Plate I

Fig. 1. Wall of testis. Full grown larva. (CHAMPY, HEID. haem.). 450 ×
Fig. 2. „ 2 day old pupa. („ „). „
Fig. 3. „ 7 day old pupa. („ „). „
Fig. 4. „ 4 day old imago. („ „). „
Fig. 5. „ 7 day old pupa. („ „). „
Fig. 6. „ Oblique section. 2 day old pupa. (BOUIN, HEID. haem.). Tunica interna is transparent. 450 ×.
Fig. 7. Partition between lobuli. 7 day old pupa. (CHAMPY, HEID. haem.). 450 ×.
Fig. 8. Ductuli efferentes testis. 2 day old larva of 5th stage. (CARNOY, HEID. haem.). 100 ×.
Fig. 9. „ 7 day old pupa. (BOUIN, HEID. haem.). 100 ×.
Fig. 10. „ 2 day old pupa. (CARNOY, HEID. haem.). 180 ×.
Fig. 11. „ „ (BOUIN, HEID. haem.). 100 ×.

Plate II

Fig. 12. Basal part of lobulus. 9 day old pupa (4 days before emergence). Many granules are found on upper part. (CHAMPY, HEID. haem.). 100 ×.
Fig. 13. Horizontal section of membrana basilaris. Pupa, 2 days before emergence. (CHAMPY, HEID. haem.). 100 ×.
Fig. 14. Basal part of lobulus. Pupa, 3 days before emergence. (CHAMPY, HEID. haem.). 100 ×.
Fig. 15. A part of Fig. 14. 450 ×.
Fig. 16. „ „ . Many cast off sheaths are accumulated on the membrana basilaris. 450 ×.
Fig. 17. Another figure on the same slide as Fig. 14. 450 ×.
Fig. 18. „ „ „
Fig. 19. „ „ „
Fig. 20. Wall of ductulus efferens testis. Pupa, 1–2 days before emergence From the same slide as Text-Fig. 7. (CHAMPY, HEID. haem.). 900 ×.

Plate III

Fig. 21. Ductuli efferentes testis. 6 day old imago. Many tracheae are shown clearly. (BOUIN, DEL. haem.). 100 ×.

Fig. 22. Basal part of lobulus and its ductulus efferens. Pupa, 2 days before emergence. Numerous granules are found on upper portion. (CHAMPY, HEID. haem.). 100 ×.

Fig. 23. A part of Fig. 22. 450 ×.

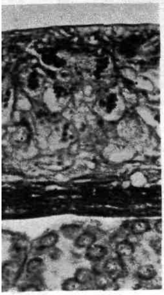
Fig. 24. Vertical section of membrana basilaris. 6 day old imago. (BOUIN, DEL. haem.). 450 ×.

Fig. 25. Ampulla ductus deferentis. Imago of the day just emerged. (CHAMPY, HEID. haem.). 100 ×.

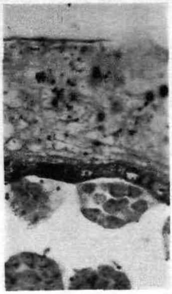
Fig. 26. Horizontal section of membrana basilaris. Pupa, 2 days before emergence. (CHAMPY, HEID. haem.). 450 ×.

Fig. 27. Vertical section of membrana basilaris. Pupa, 2 days before emergence. (BOUIN, DEL. haem.). 450 ×.

Fig. 28. Sperm bundles with bent tails near membrana basilaris. Pupa, 3 days before emergence. Membrana basilaris locates under side. (CARNOY, HEID. haem.). 450 ×.

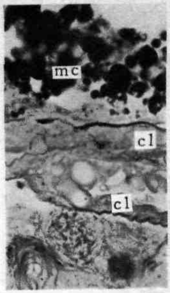


1

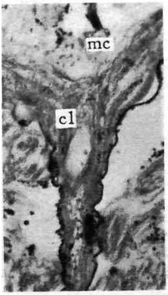


2

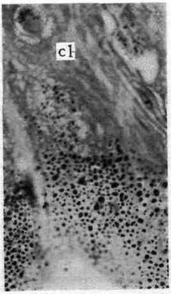
3



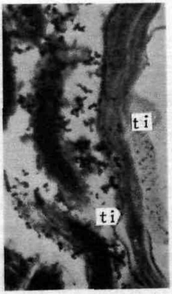
4



5

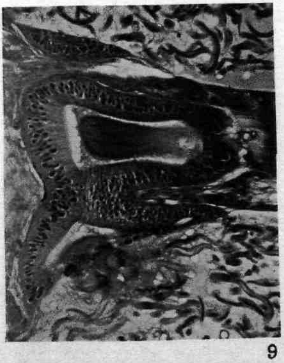


6

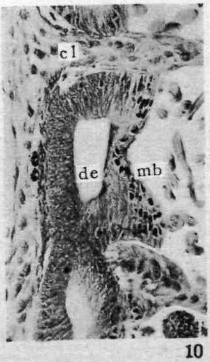


7

8

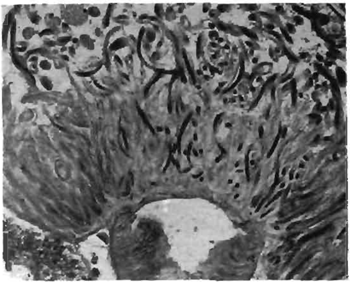


9

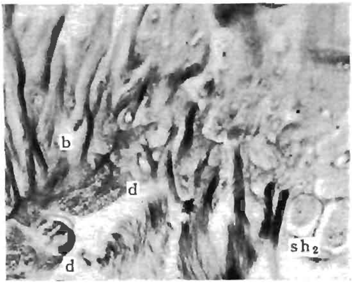


10

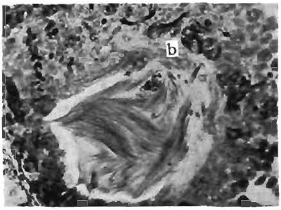
11



12



16

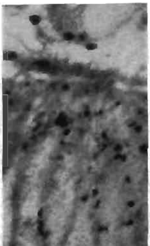


13

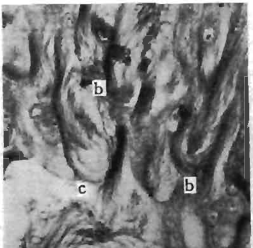
17

18

14

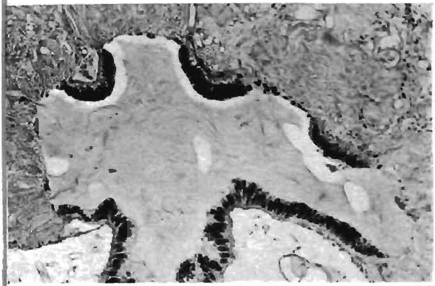


20



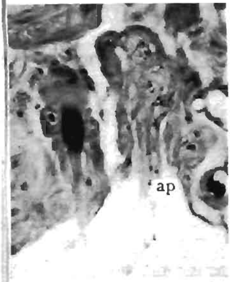
19

15

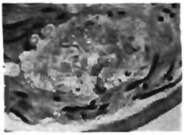


21

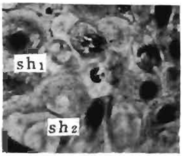
22



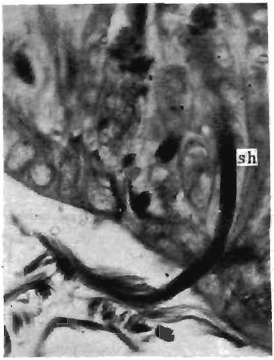
24



25



26



23

28

27

ERYSIPHACEAE OF JAPAN

By

Yasu HOMMA

Contents

	Page
Introduction	186
General Part	
Morphology and Physiology	188
Mycelia	188
Conidia	191
Forms	192
Formation of conidia	194
Fibrosin bodies	197
Germination of conidia	198
Perithecia	199
Forms and appendages	199
Structure	201
Formation of perithecia	202
Asci and ascospores	208
Hibernation	208
Host and Parasitism	209
Infection	209
Correlation of the development of the host plants to that of the powdery mildew	214
Specialization and resistance	239
Infection experiments with the conidia	239
Difference in characters between the susceptible and immune varieties of wheat	271
Systematic Part	
Historical survey of the Japanese Erysiphaceae	283
Erysiphaceae	287
Subfam. Erysipheae	288
Genus Cystotheca	289
Cyst. Wrightii BERK. & CURT.	291
Cyst. lanestris (HARKN.) MIYABE	293

	Page
Genus Sphaerotheca	295
Sph. Humuli (DC.) BURR.	296
Sph. Epilobii (WALLR.) SACC.	300
Sph. fuliginea (SCHLECHT.) POLLACCI	301
Sph. Mors-Uvae (SCHWEIN.) BERK. & CURT.	309
Sph. japonica (SALM.) HOMMA	310
Sph. pannosa (WALLR.) LÉV.	311
Oidium belonging to Sphaerotheca	313
Genus Podosphaera	313
Pod. leucotricha (ELL. & EVERH.) SALM.	314
Pod. tridactyla (WALLR.) DE BARY	315
Pod. spiralis MIYABE	317
Pod. Oxyacanthae DE BARY	318
Genus Erysiphe	320
Ery. Pisi DC.	321
Ery. Heraclei DC.	324
Ery. Polygoni DC.	326
Ery. Aquilegiae DC.	330
Ery. graminis DC.	333
Ery. Cichoracearum DC.	335
Ery. Galeopsidis DC.	340
Oidium belonging to Erysiphe	342
Genus Uncinula	343
Unc. Clintonii PECK	344
Unc. Zelkowae P. HENN.	346
Unc. clandestina (BIV. BERN.) SCHRÖT.	347
Unc. Delavayi PAT.	349
Unc. bifurcata HOMMA	349
Unc. australiana MCALPINE	350
Unc. Sengokui SALM.	351
Unc. Salmoni SYD.	352
Unc. Picrasmae HOMMA	353
Unc. Actinidiae MIYABE	353
Unc. verniciferae P. HENN.	355
Unc. Salicis (DC.) WINT.	356
Unc. simulans SALM.	359
Unc. curvispora HARA	360
Unc. septata SALM.	361
Unc. geniculata GERARD.	361
Unc. Betulae HOMMA	362
Unc. carpinicola HARA	363
Unc. Fraxini MIYABE	364
Unc. Miyabei SACC. & SYD.	365
Unc. Mori I. MIYAKE	366
Unc. Nishidana HOMMA	367

	Page
Unc. necator (SCHWEIN.) BURR.	367
Oidium belonging to Uncinula	369
Genus Typhulochaeta	369
Typh. japonica S. ITO & HARA	369
Genus Sawadaea	370
Saw. bicornis (WALLR.) MIYABE	371
Saw. Tulasnei (FUCK.) HOMMA	374
Saw. Negundinis HOMMA	375
Genus Microsphaera	376
Micr. Alni (WALLR.) SALM.	378
Micr. calocladophora ATKINS.	382
Micr. alphitoides GRIFF. & MAUBL.	383
Micr. Ligustri HOMMA	386
Micr. divaricata (WALLR.) LÉV.	387
Micr. Coryli HOMMA	388
Micr. Yamadai SYD.	390
Micr. Euphorbiae (PECK) BARK. & CURT.	391
Micr. Abeliae HOMMA	392
Micr. Lonicerae (DC.) WINT.	392
Micr. pseudo-Lonicerae (SALM.) HOMMA	393
Micr. Berberidis (DC.) LÉV.	394
Micr. Grossulariae (WALLR.) LÉV.	396
Micr. diffusa COOKE & PECK	398
Micr. Bäumleri P. HENN.	399
Micr. Viciae-unijugae HOMMA	400
Micr. Russellii CLINT.	401
Oidium belonging to Microsphaera	402
Subfam. Phyllactinieae	403
Genus Phyllactinia	403
Phyll. corylea (PERS.) KARST.	404
Phyll. moricola (P. HENN.) HOMMA	407
Phyll. Fraxini (DC.) HOMMA	409
Phyll. kakicola SAWADA	411
Phyll. Pyri (CAST.) HOMMA	412
Phyll. Actinidiae-formosanae SAWADA	414
Phyll. Quercus (MÁR.) HOMMA	414
Phyll. imperialis MIYABE	416
Phyll. Actinidiae-latifoliae SAWADA	417
Ovulariopsis belonging to Phyllactinia	418
Genus Uncinulopsis	418
Uncinulop. Shiraiana (P. HENN.) HARA	419
Subfam. Leveilluleae	422
Genus Leveillula	422
Lev. taurica (LÉV.) ARNAUD.	423

	Page
Conidial stages of Erysiphaceae	424
Erysiphe Cinnamomi SAWADA	424
Microsphaera Mougeotii LÉV.	424
Microsphaera Astragali (DC.) TREV.	425
Oidium Euonymi-japonicae (ARC.) SACC.	425
Conclusion	427
Host index	429
Literature cited	443
Plates	IV–XI

Introduction

The first record of Erysiphaceae from Japan was that by M. J. BERKELEY and M. A. CURTIS, in a paper reporting new Fungi collected in the North Pacific Exploring Expedition by CHARLES WRIGHT. In that paper, *Cystotheca Wrightii* on *Quercus stenophylla* collected in Loo-choo in April 1855 was first described as a new genus, which was considered to belong to Perisporiaceae. Since the publication of "The Monograph of Erysiphaceae" in 1900 by E. S. SALMON, a large number of our powdery mildews have been collected by Japanese mycologists, and those specimens were identified by E. S. SALMON, P. HENNINGS and P. & H. SYDOW. The reports were published in the Bulletin of the Torrey Botanical Club, Engler's Botanische Jahrbücher, Mémoires de l'Herbier Boissier, and Annales Mycologici by these authors. As these reports were published at about the same time, different names have been given to the same fungus by the different authors. From about this period, monographic treatments of Erysiphaceae have begun to appear in different countries in Europe, as for example in Italy by G. POLLACCI (1905), in Czechoslovakia by J. KLIKA (1924), in Norway by I. JØRSTAD (1925), in Croatia by V. ŠKORIĆ (1926), and in Rumania by TR. SĂVULESCU and C. SANDU-VILLE (1929). Also in this country, the new genera Sawadaea MIYABE (1914), Typhulochaeta S. ITO and HARA (1915), and Uncinulopsis SAWADA (1916) were described. The writer began studies on the Japanese species of Erysiphaceae in the year 1922, and has continued her researches up to the present time. The rich collection of specimens deposited in the Herbarium of the Faculty of Agriculture, Hokkaido Imperial University has been freely used in her studies. For the collection of the complete specimens of the conidial and perithecial stages, a long time has

been spent. For each species, the writer has endeavored to give full descriptions of both stages.

Besides, the comparative studies of all genera have been made on the form and formation of conidia as well as on the structure and formation of peritheria, because such investigations have not been carried out for all genera. The writer also studied with interest the relation between the powdery mildews and their host plants. Also, on *Erysiphe graminis* f. sp. *Tritici* parasitic on wheat, a special study on the question of specialization has been made.

In this paper, the writer endeavors to present not only a monographic study on all the Japanese species but also a consideration of many biological and morphological problems in Erysiphaceae. The paper is divided into two parts, the general and the systematic. In the former part, (1) the morphology and physiology, (2) the host and parasitism, (3) specialization and resistance are treated. In the latter part, all specimens which have been collected in every part of this country were carefully identified and classified. They are included in eleven genera, viz. Cystotheca, Sphaerotheca, Podosphaera, Erysiphe, Uncinula, Sawadaea, Typhulochaeta, Microsphaera, Phyllactinia, Uncinulopsis and Leveillula.

The writer wishes to express here her hearty thanks to Prof. Emer. K. MIYABE for his valuable suggestions and constant guidance, and moreover for his kindness in granting leave to study the numerous specimens deposited in the Herbarium of the Hokkaido Imperial University. This collection includes the many interesting specimens which were collected by himself and his assistants and pupils, accompanied sometimes with his valuable notes. The writer wishes also to acknowledge her indebtedness for the free use of his library rich in the literature relating to Erysiphaceae.

To Prof. S. ITO, the writer desires to express here her greatest gratitute for his valuable suggestions and kind guidance.

The writer has to thank Prof. Y. TOCHINAI for his kind advice; and her indebtedness is also acknowledged to the laboratory colleagues who helped her with many valuable specimens.

The writer has to thank Sir ARTHUR HILL, the Director of the Royal Botanic Gardens, Kew, for a part of the type specimen of *Phyllactinia suffulta* (REBENT.) SACC. f. *Pyri* preserved in the Herbarium of the Gardens, which he most kindly sent at her request. To Dr. C. L. SHEAR, she desires to express her thanks for the specimens of *Uncinula polychaeta* and *Microsphaera Alni* on Quercus.

The writer wishes also to express thanks to many Japanese mycologists for their kind help; to Dr. S. HORI who most kindly lent to our Institution numerous specimens from the Herbarium of the Agricultural Experiment Station, Nishigahara, Tokyo; to Prof. S. KUSANO who most kindly gave her about six hundred specimens from his private collection; to Prof. T. MATSUMOTO who very kindly sent to our Herbarium the numerous specimens from the Herbarium of the Imperial College of Agriculture and Forestry, Morioka; to the Late Dr. T. NISHIDA who contributed to our Institution many specimens from the Herbarium of the Agricultural Experiment Station, Kyushu; to Dr. KITAJIMA who very kindly sent to our Herbarium many specimens of the powdery mildews on trees and shrubs from the Herbarium of the Imperial Forestry Experiment Station, Meguro, Tokyo; to Prof. K. TOGASHI who most kindly sent the specimens collected by himself in Hokkaido and on Mt. Hayachine; to Mr. K. SAWADA who very kindly sent many interesting specimens from Formosa; to Messrs. T. YOSHINAGA, K. YOSHINO, K. HARA, S. IGATA, E. KUROSAWA, S. TANAKA and S. IWAYAMA who most kindly sent many important specimens at the writer's request.

The writer wishes to acknowledge her indebtedness for the grant by the Imperial Academy for carrying out the present research.

The specimens studied are all kept in the Herbarium of the Faculty of Agriculture, Hokkaido Imperial University, Sapporo, Japan.

General Part

I. Morphology and Physiology

Mycelia

Erysiphaceae have been classified in three subfamilies, Erysipheae, Phyllactinieae and Leveilluleae, by the character of parasitism.

In Erysipheae, the mycelial hyphae are external creeping on the surface of the host plants and sending haustoria into epidermal cells. The hyphae are abundantly produced in Cystotheca, Sphaerotheca, Microsphaera and Erysiphe; *in* Uncinula and Typhulochaeta, they are thinly effused; and in Podosphaera (except on the shoots) and Sawadaea, they are produced in intermediate quantity of the above two groups.

In the conidial stage, the hyphae are hyaline in all genera. In the perithecial stage, although they are generally hyaline, in not a few cases they turn gray, light brown, brown or blackish-brown in color. *Erysiphe Pisi, Typhulochaeta japonica* and almost all the species of Uncinula are examples belonging to the former, while *Cystotheca Wrightii, Cystotheca lanestris, Sphaerotheca Mors-Uvae, Sph. Humuli* and *Sph. japonica* belong to the latter.

For the examination of the mycelium, the following method was used.

The mycelial hyphae were stripped off from the surface of the affected leaf with needles under a magnifier, and placed on a slide-glass which had been moistened to a suitable degree. They were left exposed in the air for several minutes in order to make them stick to the surface of the slide. Iron-acetocarmine was poured on them and the slide was warmed over a gas flame for a short time.

Small pieces of the affected leaf were fixed with Flemming's weak solution which had been diluted with three times its amount of water. After 12 hours, the pieces were slightly washed in water and stained with alcoholic solution of safranin. After 24 hours, they were washed again, and the mycelial hyphae were stripped off with needles from the surface of the leaf and were examined under the microscope. The nucleus in each cell was stained dark red in color. By this method, the nuclei in the mycelial cells could be exactly counted. Also, this method was used to determine the mother cell of the conidia.

The nuclei in the vegetative mycelial cells have already been reported by R. A. HARPER in 1896 (13). Each cell includes one or many nuclei, but generally one.

The vegetative mycelium is composed of long cells, especially so in the case of *Erysiphe graminis* and *Sphaerotheca pannosa* which are produced in the late autumn. The hyphae send out branches of a similar width or somewhat slender in diameter, and each branch is delimited from the creeping hypha by a septum. It seems that the hyphae have a tendency to branch especially at the margin of the mycelial patch. The mycelial hyphae of Uncinula, Microsphaera, Sawadaea, and Typhulochaeta are flexuous, delicate and easily broken, while those of Sphaerotheca, Cystotheca, Podosphaera, and Erysiphe are slightly flexuous and strong. The mycelium produced in the late autumn is more strong, smooth and thick-walled, and sometimes shin-

ing, especially so in *Erysiphe graminis* and *Sphaerotheca pannosa*, in which cases the mycelial branches are rarely produced. In Cystotheca, special hairy branches are produced from the vegetative hyphae.

From the mycelial hyphae, appressoria of an irregularly lobed shape are produced. They are firmly fastened on the epidermal surface of the host plant.

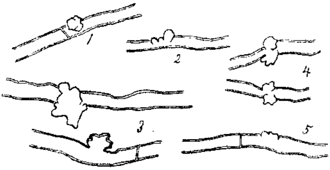


Fig. 1. Appressoria. (×550)

1. *Sphaerotheca fuliginea* (SCHLECHT.) POLLACCI on *Taraxacum ceratophorum* DC.
2. *Podosphaera tridactyla* (WALLR.) DE BARY on *Prunus triflora* ROXB.
3. *Erysiphe Polygoni* DC. on *Polygonum aviculare* L.
4. *Microsphaera Alni* (WALLR.) SALM. on *Castanea crenata* SIEB. & ZUCC.
5. *Phyllactinia imperialis* MIYABE on *Paulownia tomentosa* STEUD.

The hyphae send haustoria into the epidermal cells of the host plant, and rarely, into the underlying mesophyll cells in the case of Uncinula. The haustoria are globose, subglobose or ellipsoidal in shape, sometimes in irregular forms, and about 14.4–16.8 × 7.2–14.4 μ in size (Pl. VI, D, figs. 1–8). In *Erysiphe graminis*, the haustoria produce finger-like branches on one or both sides which are larger than those of other species, about 57.6–70.8 × 4.8–10.8 μ in size. The haustoria at first appear as small globular bodies at the apex of the penetration tube, and they gradually grow, assuming special forms peculiar to each species.

In Phyllactinieae, the mycelial hyphae are of two forms, external and internal. From the external mycelial hyphae, special branches are sent through the stomata into the intercellular spaces of the mesophyll. In Phyllactinia, the external hyphae are more numerous than the internal, and on them we can notice here and there poorly developed appressoria with which they fasten to the surface of the

leaf, but from which haustoria have never been found penetrating into the epidermal cells. The internal mycelium is simple or branched, and it sends haustoria, 1 or 2 in number (usually 1) into the parenchyma or palisade cells, with which it comes in contact. When the internal mycelium reaches a certain length, it is checked in growth. The internal mycelium is composed of 1–3 cells (Pl. VI, D, fig. 10).

In 1899, the presence of the internal mycelium was first recognized in the intercellular spaces of the mesophyll of the leaves of Berberis and Corylus by E. PALLA (26). In 1900, E. S. SALMON (32) and G. SMITH (41) reported on the internal mycelia and haustoria. In 1903, G. DELACROIX (7) reported on those of *Ovulariopsis moricola*. In 1930, K. SAWADA (38) published a paper under the title "On the systematic investigation of Phyllactinia in Formosa" (in Japanese), in which he used for the criteria of classification the characters of the internal mycelia and haustoria.

In Uncinulopsis, the internal mycelium is more developed than that of Phyllactinia, while the characters of the external mycelia are similar to those of Uncinula and Sawadaea (Pl. VI, D, fig. 9).

In *Leveilluleae*, the external mycelia are very scanty, and the internal mycelia spread widely in the intercellular spaces of the mesophyll of the leaves and send the haustoria into the surrounding parenchyma cells. The conidiophores are branched from the internal mycelia and are sent out through the stomata (Pl. VI, D, fig. 11).

Conidia

The conidia of Erysiphaceae are produced in a chain on the conidiophore. There are two types in the formation. In one of them, the matured spore is solitary remaining at the apical end of the conidiophore and the second spore grows after the first matured spore has fallen down. In another type, the spores in a chain mature gradually downward from the apical one. Microsphaera, Uncinula, Uncinulopsis, Leveillula and Erysiphe Polygoni-section belong to the former type, while the others are of the latter type. In the former type, the spores rarely form a chain under certain conditions of the environment. In *Uncinula Sengokui* and *U. Actinidiae*, the conidia are sometimes, but not often, catenated in a chain with two or three matured spores when they are luxuriantly formed in nature.

1. Form

Cystotheca. The matured conidia are borne in a chain, the free end of the terminal spore is obtusely pointed, and the other spores are barrel-shaped, including vacuoles, granules and well-developed fibrosin bodies. The septum of the conidiophore is about 17 μ above the branching point of the mycelium.

Sphaerotheca. The matured conidia are produced in a chain 4–9 in number; they are subglobose or ellipsoidal in shape, including well-developed fibrosin bodies.

Podosphaera. The matured conidia are produced in a chain 4–5 in number; they are subglobose or ellipsoidal in shape, including well-developed fibrosin bodies. They are more or less smaller than those of Sphaerotheca.

Erysiphe. There are three types of conidia in this genus. The first type belongs to the Polygoni-section in which the matured spore is produced singly at the apex. It is elongate-ellipsoidal or cylindrical in shape, including vacuoles and granules, but lacking well-developed fibrosin bodies. The conidiophore is separated directly from the mycelium by a septum. The second type is represented by the species belonging to the Cichoracearum-section, in which the matured spores are produced in a chain, and they are ellipsoidal or oblong in shape, including the vacuoles and granules, but lacking well-developed fibrosin bodies. The conidiophore is sometimes branched laterally from the mycelium. To the third type belongs the Graminis-section, in which the matured spores are produced in a chain; they are elongate-ellipsoidal in shape. The conidiophore has a bulbous swelling at the base, and the septum lies close to the creeping mycelium or slightly above. The contents of the conidia are similar to those of the first and second types.

Uncinula. The conidia are found always scantily. They are ellipsoidal or elongate-ellipsoidal in shape. The conidiophore branches from the creeping mycelium. The conidia contain vacuoles and granules, lacking well-developed fibrosin bodies.

Typhulochaeta. The conidia have not yet been found.

Sawadaea. This genus has conidia of micro- and macro-forms. The matured conidia of both types are produced in a chain. The micro-conidia are globose or subglobose in shape, and they are very small, including well-developed fibrosin bodies. The macro-conidia are ellipsoidal in shape, including well-developed fibrosin bodies.

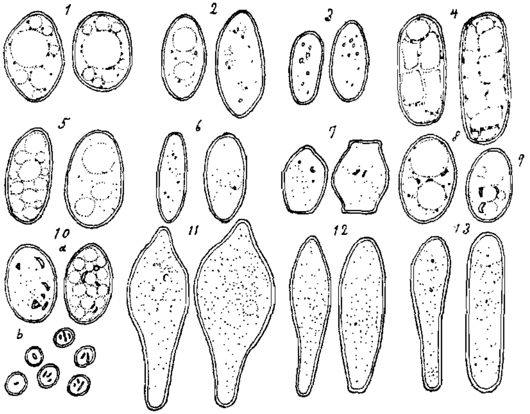


Fig. 2. Conidia. (×550)

1. *Microsphaera alphitoides* GRIFF. & MAUBL. on *Quercus dentata* THUNB.
2. *Microsphaera Grossulariae* (WALLR.) LÉV. on *Sambucus Buergeriana* BLUME var. *Miquelii* NAKAI
3. *Uncinula Salicis* (DC.) WINT. on *Salix Hultenii* FLOD. var. *angustifolia* KIMURA
4. *Erysiphe Polygoni* DC. on *Polygonum aviculare* L.
5. *Erysiphe Cichoracearum* DC. on *Artemisia vulgaris* L. var. *kamtschatica* BESS.
6. *Erysiphe graminis* DC. on *Triticum sativum* LAM. var. *vulgare* HACK.
7. *Cystotheca lanestris* (HARKN.) MIYABE on *Quercus major* NAKAI
8. *Sphaerotheca fuliginea* (SCHLECHT.) POLLACCI on *Lactuca Raddeana* MAXIM.
9. *Podosphaera tridactyla* (WALLR.) DE BARY on *Prunus triflora* ROXB.
10. *Sawadaea Tulasnei* (FUCK.) HOMMA on *Acer pictum* THUNB. var. *eupictum* PAX. a. Macro-conidia. b. Micro-conidia.
11. *Phyllactinia Fraxini* (DC.) HOMMA on *Alnus japonica* SIEB. & ZUCC. var. *arguta* CALL.
12. *Uncinulopsis Shiraiana* (P. HENN.) HARA on *Celtis sinensis* PERS.
13. *Leveillula taurica* (LÉV.) ARNAUD on *Capsicum annuum* L.

Microsphaera. The conidia belonging to the Alni-section are subglobose or ellipsoidal in shape. In the Diffusa-section, the conidia are elongate-ellipsoidal, oblong or cylindrical, including vacuoles and

granules, but lacking well-developed fibrosin bodies. The conidiophore has the septum at the point of branching from the creeping mycelium or sometimes slightly upward.

Phyllactinia. The matured conidia are produced singly at the apex and they are the largest among the conidia in Erysiphaceae. Also, their form differs entirely from that of the other genera. They are clavate or broad-clavate in shape and those in some species have a papillate apex, including granules, vacuoles and rarely well-developed fibrosin bodies.

Uncinulopsis. The matured conidia are produced singly at the apical end. They are elongate-ellipsoidal or clavate in shape, and smaller in size than those in Phyllactinia. The conidiophore presents a true spiral at the base.

Leveillula. The matured conidia are produced singly at the apex, and they are clavate or cylindrical in shape. The conidiophore branches from the internal mycelium at the opening of a stoma.

Although the genera in Erysiphaceae could be distinguished from one another by the conidial forms, the species belonging to the Polygoni-section of Erysiphe, the Diffusa-section of Microsphaera and one part of Uncinula have conidia similar to one another, and their classification is very difficult.

2. Formation of conidia

Erysipheae. In 1912, E. FOËX (8) reported the following four types in the formation of conidia.

1st. type—*Erysiphe graminis.* The basal cell is the conidiophore, which produces at its apex a spore-mother cell which divides into two conidia, and another new spore-mother cell is again formed on the apex of each conidiophore, repeating the process.

2nd. type—*Erysiphe Polygoni, Uncinula Salicis, Microsphaera Mougeotii, Oidium Evonymi-japonici,* and *Oidium alphitoides.* The spore-mother cell divides into a conidium and a new spore-mother cell, repeating the process. A fully matured conidium is formed at the end of the chain, followed by several elongated immatured spores, called pedicellate cells by Foëx.

3rd. type—*Phyllactinia corylea.* This type is of the same form as the 2nd. type, but the pedicellate cells are composed of slender cells and frequently of many cells.

4th. type—*Oidiopsis taurica.* The conidiophores arising from the internal mycelium produce pedicellate cells composed of many cells. A single conidium is formed on each conidiophore.

In 1913, the same author (10) described the development of the conidia of *Sphaerotheca Humuli* var. *Humuli* parasitic on *Erodium malacoides* and also of *Sphaerotheca Humuli* var. *fuliginea* on *Calendula arvensis.* The basal cell (conidiophore) is unceasingly divided, forming spore-mother cells. A spore-mother cell divides into two cells, each cell developing into a normal conidium. In *Sphaerotheca pannosa* on *Rosa*, *Erysiphe Cichoracearum* on *Senecio vulgaris*, and *Podosphaera Oxyacanthae* on apricot, the formation of the conidia belongs to the first type. In 1925, the same author (11) (p. 418) reported again on the formation of the conidia of *Sphaerotheca pannosa* parasitic on *Rosa*, *Podosphaera Oxyacanthae* var. *tridactyla* on *Armeniaca vulgaris*, *P. leucotricha* on *Malus pumila* var. *domestica*, and *Microsphaera Mougeotii* on *Lycium barbarum.* In *Sphaerotheca pannosa*, *Podosphaera Oxyacanthae* var. *tridactyla*, and *P. leucotricha*, the conidiophore divides at its apex into two cells, the short upper cell dividing again into two cells. The upper one enlarges, becoming a conidium. The under one is divided continually and the conidia are thus formed in a chain. In Podosphaera, eight cells are formed in a chain on the conidiophore, and the uppermost four cells become the matured conidia. In Microsphaera, the conidiophores and conidia are produced in the same manner as those in Sphaerotheca. In this case, only the terminal cell becomes a matured conidium.

In 1905, E. S. SALMON (36) reported that when *Erysiphe Polygoni* and *Oidium Euonymi-japonici* forming abundant tufts of conidiophores are placed in a damp and still atmosphere, the conidia are produced in a chain, although normally only a single matured conidium is produced on a conidiophore.

For the study of the formation of conidia the following species were used.

Sphaerotheca fuliginea on *Taraxacum ceratophorum* (Pl. IV, A, fig. 1), *Podosphaera tridactyla* on *Prunus triflora* (Pl. IV, A, fig. 2), *Erysiphe Cichoracearum* on *Plantago major* var. *asiatica* (Pl. IV, A, fig. 3), *E. graminis* on *Triticum vulgare*, (Pl. IV, A, fig. 4), *Sawadaea Tulasnei* on *Acer pictum*, *Erysiphe Polygoni* on *Polygonum aviculare* (Pl. IV, A, fig. 5), *Microsphaera Picrasmae* on *Picrasma quassioides*,

M. alphitoides on *Quercus crispula* (Pl. IV, A, fig. 7), and *Uncinula Actinidiae* on *Actinidia arguta* (Pl. IV, A, fig. 6). The experiments were made using the same method as that employed in the case of the mycelial staining. Nuclear staining is found necessary to discriminate the spore-mother cells from the conidial cells. In all samples, at first, the incipient conidiophore is formed as a branch from the creeping mycelium on the surface of the host plant, and it is easily distinguished from the ordinary mycelial branches by its larger size and position. The young conidiophore assumes a cylindrical form, and when it reaches about 50 μ in length, it is delimited from the mycelium by a septum. The young conidiophore is divided by a septum at its upper portion, forming a new spore-mother cell. The nucleus of the young conidiophore divides into two, one of which is included in the new spore-mother cell, and the other remains in the conidiophore. The spore-mother cell divides again into two cells, the apical one becoming a normal conidium when matured, and the lower spore-mother cell dividing again into two cells. Similar divisions are repeated forming a chain of conidiospores. The spore-mother cell is always left remaining between the immatured conidium and conidiophore. In *Sphaerotheca fuliginea, Erysiphe Cichoracearum, Podosphaera tridactyla, Erysiphe graminis,* and *Uncinula Actinidiae* (when the conidia were produced most abundantly), 5 to 12 cells are formed in a chain on the conidiophore, and the uppermost 2 to 5 cells become matured conidia. In *Erysiphe graminis* and *Podosphaera tridactyla,* when the conidia are luxuriantly produced under favorable conditions, the conidiophore sometimes divides again into two cells, the upper one of them forming a new spore-mother cell. In *Microsphaera alphitoides, Sawadaea Tulasnei, Erysiphe Polygoni,* and *Uncinula Actinidiae* (when the conidia are produced in a normal condition), 4 cells are formed in a chain on the conidiophore, and only the terminal cell becomes a matured conidium while the second cell develops into a matured conidium after the first matured spore has fallen down.

Phyllactinieae. In 1902, F. W. NEGER (24) reported that if a leaf of Corylus producing vigorous tufts of conidiophores be placed in a damp and still atmosphere, the conidia formed remain connected, making ultimately a chain of 2–4 conidia. In 1925, E. FOËX (11) noted the conidia formation of *Phyllactinia corylea* on *Paliurus australis.* According to him, the young conidiophore develops as a long

cylindrical cell, branching erect from the mycelium. The conidia are produced in the same manner as those in Microsphaera, 2–4 cells being formed in a chain. The terminal one only becomes a matured conidium of ovoid-conical shape.

The conidia on *Paulownia tomentosa* (Pl. IV, A, fig. 8) were used for the study of the conidia formation in Phyllactinia. The mode of conidia formation resembles that in Uncinula and Microsphaera. But, the young conidiophore is not for a long time separated from the creeping mycelium by a septum. The septum is produced at about 70–100 μ above the branching point. The conidiophores are very long and slender. The conidia are produced in a chain of always 3 in number. Only the terminal conidium becomes matured. In Uncinulopsis, no living samples were available for examination. But, judging from the dry materials, the conidia formation may be similar to that in Phyllactinia.

3. Fibrosin bodies

In 1887, the fibrosin bodies contained in conidia and conidiophores of *Podosphaera Oxyacanthae* on *Crataegus Oxyacantha* were first reported by W. ZOPF (48). They were called "Fibrosinkörper". In 1912 and 1925, FOËX (9, 11) noted their chemical natures and formation. The writer (16) also reported on them in a paper entitled "On the fibrosin body of Erysiphaceae" (in Japanese) in 1928.

The fibrosin bodies are the small shining bodies contained in the cells of every organ of all species belonging to the family Erysiphaceae. There are two types, one of which assumes the special forms of a disk, cylinder, cone, or truncated cone which are hollow inside except the disk-shaped one. The other type is of a granular form. The former is called the well-developed fibrosin bodies, while the latter the granular fibrosin bodies.

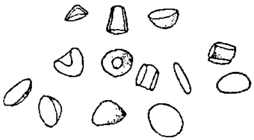


Fig. 3. Well-developed fibrosin bodies which are included in the conidia and conidiophores of *Podosphaera leucotricha* (ELL. & EVERH.) SALM. on *Malus baccata* BORCKN. var. *mandschurica* SCHNEID. (×1350)

The well-developed fibrosin bodies develop prominently in the conidia and conidiophores of Cystotheca, Podosphaera, Sphaerotheca, Sawadaea, and some species of Uncinula. These bodies are consumed when the conidia have germinated. They are considered to be a reserve material.

As the results of tests by staining, and by enzymic and chemical reactions, the fibrosin bodies seem to be a β-VI-carbohydrate containing N (16).

4. Germination of conidia

When the conidia are placed under a favorable condition, they produce germ-tubes after 17 hours to 4 days. The germ-tube is mostly single to a conidium, but frequently 2 or 3 tubes are formed. After 3 days from the germination, the appressoria appear at the apices of the germ-tubes. The incubation period for the germination differs with the degree of the ripening of the conidia, and with the environmental factors.

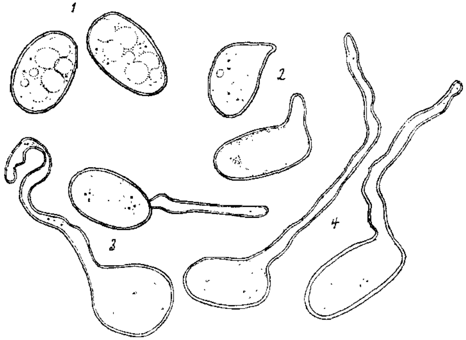


Fig. 4. Germination of conidia of *Erysiphe Cichoracearum* DC. on *Plantago major* L. var. *asiatica* DECNE. (×550)

1. Conidia when germination experiment started.
2. Conidia after 17 hours from the start of germination experiment.
3. Conidia after 41 hours from the start of germination experiment.
4. Conidia after 65 hours from the start of germination experiment.

After 6 hours from the beginning of the germination experiment, the vacuoles begin to disappear and the fibrosin bodies become gradually smaller in size and indistinct. At the time when the germ-tubes are pushed out, the fibrosin bodies generally disappear.

TABLE 1.

Changes observed in the cell contents of the conidia of *Podosphaera tridactyla*, *Erysiphe Polygoni* and *Sphaerotheca Humuli* during their germination.

Aug. 27	a.m. 5	9	11	p.m. 1	3	5	7	9
Podosphaera tridactyla on *Prunus triflora*	Germination experiment was started	No change	—	Fibrosin bodies became indistinct	—	—	Fibrosin bodies entirely disappeared	—
Erysiphe Polygoni on *Polygonum aviculare*	,,	,,	—	Vacuoles became indistinct	—	Granules decreased in number	—	Germ-tube was produced
Sphaerotheca Humuli on *Agrimonia pilosa*	,,	,,	—	Fibrosin bodies became smaller in size	—	Vacuoles became indistinct	Fibrosin bodies disappeared	Small granules only remained

In the above experiments, the conidia of Sphaerotheca and Podosphaera did not germinate within 16 hours.

In the conidia of Phyllactinia, one to three germ-tubes are produced at their upper shoulders generally after about 24 hours from the time of sowing.

Perithecia

1. Forms and Appendages

Erysipheae. Perithecia in their earliest stage appear as exceedingly small hyaline shining bodies under a magnifier. As they

develop gradually, they begin to turn yellow. In this stage, the perithecia are always spherical in form in all species. When the perithecia become matured, they turn brown, deep brown and brownish black in color. In Cystotheca, Sphaerotheca, and some species of Erysiphe, Microsphaera, and Uncinula, the matured perithecia are spherical. In Sawadaea, Typhulochaeta, and a majority of the species belonging to Erysiphe, Microsphaera, and Uncinula, they are depressed-globose or lenticular in shape.

In Cystotheca, the appendages are very scanty or generally wanting; in Podosphaera, those of the Tridactyla section arise erect at the upper part of the perithecium, while in the Oxyacanthae section, they are produced from about the equatorial region; in Sphaerotheca, Uncinula, Microsphaera, and Erysiphe, the appendages are generally produced from the equatorial portion or from the part nearer to the base; and in Sawadaea and Typhulochaeta, they spring from the upper part of the perithecium forming broad coronate rings of about 3 rows and also those perithecia turn over upside down when matured.

The appendages of the perithecia of Sphaerotheca and Erysiphe are hyaline, pale brown or deep brown in color, aseptate or septate, simple or irregularly branched and sometimes interwoven in the mycelial hyphae. Those of Uncinula and Sawadaea are hyaline, or brown in some species of Uncinula, simple, dichotomously or trichotomously branched, aseptate or septate, and uncinate or circinate at their apices. Those of Microsphaera and Podosphaera are hyaline or brown in color, 2–6 times dichotomously branched at the apical portion. aseptate or 1–3 septate. Those of Typhulochaeta are clavate in shape, hyaline and aseptate.

Phyllactinieae. The young perithecia coincide in shape with those in Erysipheae. The matured perithecia are, however, lenticular or concave in shape, and their diameter is always larger than that in Erysipheae. The perithecia of Uncinulopsis can be distinguished from those of Uncinula only by their larger size and the appendages are the same in character.

The appendages of Phyllactinia are always simple, excepting a case in which abnormal branches are produced. They are needle shaped, having a bulbous base. They are produced from the special large cells of the outer perithecial wall, and these cells are arranged in the equatorial zone of the perithecium. The bulbous part of the

appendage is first produced and then the needle part grows straight out. When the perithecia are matured, they are lifted up on the surface of the leaves by the reflexed appendages, and then they turn over upside down. The penicillate cells are produced at the apical part of the perithecium at the same time with the formation of the appendages. In the formation of the penicillate cells, some of the outer wall cells at the apical part of the perithecium enlarge into oblong-shaped cells, from the apical ends of which numerous branches are produced in a rosette form. When the perithecia are turned over, by the branches of the penicillate cells which have made a gelatinous modification, they adhere to the surface of the leaves.

2. Structure

The wall of the matured perithecium is divided into two layers, the inner and the outer. For the study of the perithecial structure, the usual paraffin method was used. The sections were stained with safranin and gentian-violet. The outer wall was stained reddish-brown in color and the inner wall a violet color. The outer wall is composed of large cells whose wall is thickened and lignified. The nucleus and cytoplasm could not be found in them. The inner wall is composed of small hyaline pseudo-parenchymatous cells including 1 or 2 nuclei.

Erysipheae. The perithecia of *Cystotheca lanestris* on *Quercus serrata* (Pl. IV, B, fig. 2), *Cyst. Wrightii* on *Quercus glauca* (Pl. IV, B, fig. 1), *Podosphaera tridactyla* on *Prunus triflora* (Pl. IV, B, fig. 4), and *Sphaerotheca fuliginea* on *Taraxacum ceratophorum* (Pl. IV, B, fig. 3) were used for the study of the perithecial structure of the single-ascus group. In Cystotheca, the outer perithecial wall is composed of the collapsed cells of 4–5 layers, while the inner wall is always of 2 layers. The innermost layer of the inner wall is composed of cells of larger size surrounding an ascus, while the outer layer becomes degenerate, when the perithecia are matured. When pressure is applied to the perithecium, the innermost layer enclosing an ascus easily separates from the ruptured outer wall. Cystotheca is distinguished from Sphaerotheca by the difference in this structure of the perithecial wall. Judging from the perithecial structure, Cystotheca belongs evidently to Erysiphaceae, having a close affinity to Sphaerotheca. In *Podosphaera tridactyla* and

Sphaerotheca fuliginea, the outer wall is composed of 2 or 3 layers of thick-walled cells while the inner wall is of about 2 layers of ordinary structure.

The perithecia of *Erysiphe Cichoracearum* on *Plantago major* var. *asiatica* (Pl. IV, B, fig. 7), *Uncinula Actinidiae* on *Actinidia arguta* (Pl. IV, B, fig. 8), *Sawadaea Tulasnei* on *Acer pictum* (Pl. IV, B, fig. 10), *Typhulochaeta japonica* on *Quercus serrata* (Pl. IV, B, fig. 5) and *Microsphaera Alni* on *Picrasma quassioides* (Pl. IV, B, fig. 9) were used for the study of the perithecial structure of the many-asci group. In this group, the boundary line of the inner and outer walls is indistinct, and the inner-wall cells are gradually continuous to the pseudo-parenchyma cells surrounding the asci. In Erysiphe, the outer and inner walls are both composed of 2 or 3 layers. In Uncinula, the outer wall is composed of 3 layers of large cells, and the inner wall is of 2–3 layers. In Sawadaea, the outer wall is composed of 3–5 layers, while the inner wall is of 2 or 3 layers. On the outer surface of the outer wall, the hyaline cells are arranged in a disconnected layer, and the appendages are grown from some of these cells. In Typhulochaeta, the outer wall is composed of more or less depressed cells. The inner wall is of 2–3 layers. In Microsphaera, the outer wall is composed of 3–4 layers, while the inner wall is of 2–3 layers.

Phyllactinieae. The outer wall is composed of 3–6 layers made up of thick-walled cells. The inner wall is of 3–7 layers of pseudoparenchymatous cells, which are gradually continuous to the pseudoparenchyma cells surrounding the asci. These cells are almost always binucleate. In the under half of the outer perithecial wall in Phyllactinia, 2–3 layers on the outside are composed of especially large cells of irregular forms and arrangement (Pl. IV, B, figs. 6, 11).

3. Formation of perithecia

The perithecia formation of Erysiphaceae has been studied by many authors. In 1863, the fundamental work on the development and structure of the ascocarp of *Sphaerotheca Castagnei* (*Sph. Humuli*) was done by A. DE BARY (4). The oogonium and antheridium were found to be formed at the crossing or touching point of two special hyphae. In 1870, the same author (5) reported on the

perithecia formation of *Erysiphe communis* on *Trifolium medium*, *Podosphaera Castagnei* on *Melampyrum silvaticum*, *Impatiens Noli-tangere* and *Taraxacum*, and *Erysiphe Umbelliferarum* on *Angelica silvestris*. R. A. HARPER (12, 14) published very important papers as the results of his extensive studies on the perithecia formation of *Sphaerotheca Castagnei*, *Phyllactinia corylea*, *Erysiphe communis*, and *E. Cichoracearum* from 1895 to 1905. Especially, the investigation of *Phyllactinia corylea* is the most valuable cytological contribution. In 1906, V. H. BLACKMAN and H. C. L. FRASER (2) reported on the ascocarp formation of *Sphaerotheca Humuli* parasitic on *Humulus*. In 1906, P. CLAUSSEN (3) published a summary report on the development history of Ascomycetes. In 1907, cytological studies of the perithecia formation were made in *Microsphaera Alni* by M. C. SAND (37), especially the nuclear divisions in the ascus were observed. In 1907, P. A. DANGEARD (6) noted on the perithecia formation of *Erysiphe Polygoni* parasitic on *Pisum sativum* and *Ranunculus acris*, *E. Cichoracearum* on *Sonchus oleraceus*, *Phyllactinia corylea* on *Corylus Avellana*, *Uncinula Salicis* on *Populus*, and *Sphaerotheca Humuli* on *Humulus*. In 1911, Ö. WINGE (47) reported on that of *Sphaerotheca Castagnei* parasitic on *Melampyrum*. In 1914, N. BEZSSONOFF (1) reported on the perithecia formation of *Sphaerotheca Mors-Uvae*, *Sph. Humuli*, *Microsphaera Astragali*, *Podosphaera leucotricha*, *Erysiphe Polygoni*, and *Uncinula Salicis*. In 1931, observations were made on the process of the perithecia formation in *Erysiphe aggregata* parasitic on *Alnus incana* by E. A. WENTZEL (46). In 1933, the writer (18) reported that the ascogonial and antheridial hyphae of *Sphaerotheca fuliginea* parasitic on *Taraxacum ceratophorum* are formed on a single mycelium derived from the monosporic infection.

Method. (1). The experiments were made using the same method as that employed in the case of mycelia staining with iron aceto-carmine. By this method, the relation between the antheridial and ascogonial hyphae and between the young antheridium and ascogonium became clearly differentiated.

(2). Small pieces of the affected leaf on which perithecia of different stages had been produced were put in water, the air was removed from the materials by means of a hydraulic suction pump and they were transferred to the fixing fluid. For the fixing fluid, FLEMMING's weak solution or the same diluted with

three times its amount of water, CARNOY's solution, BOUIN's solution or ALLEN's modification of BOUIN's solution, and formalin alcohol were used. In the case of young stage, the use of dilute FLEMMING's weak solution has obtained a good result. The sections were cut 5–7 μ in thickness, and Heidenhain's iron-alum haematoxylin, safranin and gentian-violet, or crystal-violet were used for staining.

Erysipheae. *Cystotheca lanestris* on *Quercus serrata*, *Sphaerotheca fuliginea* on *Taraxacum ceratophorum*, and *Podosphaera tridactyla* on *Prunus triflora* were used for the study of the perithecia formation of the single-ascus group. In *Sphaerotheca fuliginea*, for the investigation on the origin of the ascogonial and antheridial hyphae, a single spore inoculation was made with the method and arrangement as already reported in the papers, "Homothallism in *Sphaerotheca fuliginea* (SCHLECHT.) POLLACCI" and "A life-cycle of *Sphaerotheca fuliginea* (SCHLECHT.) POLLAC. parasitic on *Taraxacum ceratophorum* DC." by the writer in 1933 and 1934 (17, 18).

The antheridium and ascogonium on the mycelial hyphae which were produced by the single spore inoculation entirely coincided with those of the natural formation. The perithecia are formed from the center of the mycelial patch. The ascogonium and antheridium are formed at the place where the ascogonial and antheridial hyphae cross each other and touch (Pl. V, figs. 1, 2, 4 and Pl. VI, A, figs. 3, 8). The antheridial hypha is more slender than the ascogonial (Pl. V, fig. 5). Both hyphae always run side by side or coil about each other or cross each other. The ascogonium and antheridium seem to arise simultaneously, and the former is larger than the latter from the start, also the ascogonium grows more rapidly (Pl. V, figs. 1, 3 and Pl. VI, A, fig. 1). Sometimes both organs swell up at the base, adhere closely to each other and become more or less spirally twisted (Pl. V, fig. 4). At first, they are single cell and delimited from the sexual hyphae by a septum (Pl. VI, A, fig. 1). Later, they divide into two cells (Pl. VI, A, fig. 2). The apical cell is the ascogonium or antheridium, and the under one is the stalk cell. The ascogonium soon becomes larger than its stalk cell, while the antheridium remains smaller. The ascogonium grows straight up forming a subglobose body, while the antheridium clinging to the side of the ascogonium adheres at its upper part (Pl. VI, A, fig. 5). The antheridial nucleus divides into two nuclei, one of which goes into the ascogonium. Two, or rarely three, nuclei are found enclosed in the

ascogonium, and one of them, which is apparently the male nucleus, is always more or less smaller than the other (Pl. VI, A, figs. 6, 7).

The primary perithecial wall cells are formed from the twisting hyphal cells springing upward from the stalk cell of the ascogonium (Pl. VI, A, figs. 4, 5). The enclosing wall thus formed is closed at the upper part of the ascogonium. At this time, the antheridium is seen adhering at the outer side of the primary perithecial wall. The secondary perithecial wall cells develop between the ascogonium and the first wall (Pl. VI, A, figs. 7, 9). In this stage, the antheridium withers and gradually disappears. Thus, when about 4 to 5 layers of the wall are developed, the appendages begin to arise from the region nearer to the base of the perithecium, and the perithecial hyphae are sent out from its basal portion (Pl. VI, A, fig. 17). The outer two layers are composed of larger cells, whose walls gradually turn brown in color (Pl. VI, A, figs. 14, 16). These layers constitute the so-called outer wall. The inner 2 or 3 layers make up the inner wall, whose cells are always hyaline and binucleate (Pl. VI, A, fig. 14).

At the time when two layers of the outer perithecial wall are developed, the male and female nuclei in the ascogonium conjugate to form a more or less large nucleus (Pl. VI, A, fig. 10). Then, the ascogonium divides into two cells (Pl. VI, A, fig. 11). The upper cell divides again into two cells (Pl. VI, A, fig. 12). The same process is repeated, thus forming 4 to 5 cells (Pl. VI, A, fig. 13). The penultimate cell is always more or less larger than the rest, and its reaction to the staining solution differs from the others. The second cell only is clearly stained a red color by safranin, while the rest of the cells take violet color from gentian-violet. This penultimate cell develops into an ascus. In the young ascus, a single large nucleus is found (Pl. VI, A, fig. 14). This nucleus divides three times, and eight free ascospores are formed. Eight chromosomes could be counted in the first nuclear division, but it was difficult to detect them in the second and third divisions, as these divisions generally take place enclosed in the intact nuclear wall.

In *Podosphaera tridactyla* (Pl. VI, B, fig. 2) and *Cystotheca lanestris* (Pl. VI, B, fig. 1), single spore inoculations were always unsuccessful. The perithecia formation was similar to that of Sphaerotheca.

Erysiphe Cichoracearum on *Plantago major.* var. *asiatica* (Pl. VI, B, fig. 3), *Uncinula Actinidiae* on *Actinidia arguta* (Pl. VI, B,

fig. 4), *Sawadaea Tulasnei* on *Acer pictum* (Pl. VI, B, fig. 5), *Typhulochaeta japonica* on *Quercus serrata* (Pl. VI, B, fig. 6), and *Microsphaera Alni* on *Picrasma quassioides* (Pl. VI, B, fig. 7) were used for the study of the perithecia formation of the many-asci group. In *Erysiphe Cichoracearum*, single spore inoculation was made with a conidium using the same method as that employed in the case of Sphaerotheca. Between July 14, 1931 and Nov. 8, 1932, 62 pots of *Plantago major* were inoculated each with a single spore. Nine pots out of them were found infected after 7 to 19 days. But the perithecia did not appear in every case. Abundant perithecia were produced on the stock plant which had been left to natural infection. In Sept. and Nov. 1933, 8 pots which were covered with large glass tubes were inoculated with numerous conidia. The perithecia did not appear on the mycelial patches even after 3 months. The young perithecia were produced on the leaves of the stock plant on Oct. 25, 1933. The species may be heterothallic in nature. This point will be discussed in Chapter II.

The perithecia formation in *Erysiphe Cichoracearum* (Pl VI, B, fig. 3, a–h) is similar to that of Sphaerotheca. The ascogonium divides into 4 or 5 cells. The ascogenous hyphae may be branched from the second cell, which is found including two nuclei. As shown in Plate VI, B, Fig. 3, h, the young ascus is formed from the ascogenous hyphae. In this way many asci are produced. The nuclear division in each ascus is similar to that in the case of Sphaerotheca. Eight free ascospores are formed. In other species, the perithecia formation was similar to that of Erysiphe, as shown in Plate VI, B.

Phyllactinieae. *Phyllactinia imperialis* on *Paulownia tomentosa*, and *Uncinulopsis Shiraiana* on *Celtis sinensis* were used for the study of the perithecial formation. In Phyllactinia, the ascogonium and antheridium are formed on the ascogonial and antheridial hyphae and they adhere to each other as in the case of Erysiphe. The primary perithecial wall cells also arise from the stalk cell of the ascogonium by the same process as those in the case of Erysiphe. These cells grow up somewhat in a spiral manner enclosing the ascogonium. The formation of perithecial wall and asci coincides with that of Erysiphe. The nucleus in the young ascus divides three times and eight free nuclei are formed. Generally 2 or 3 matured ascospores are developed, the rest being degenerated. In Uncinulopsis, the perithecial formation was similar to that of Phyllactinia.

HARPER (14) reported that the oogonia and antheridia arise as lateral branches from separate hyphae, though it seems fairly clear, from the circular shape of the infected spots in most cases in Phyllactinia, that both these hyphae belong to a single mycelium, which in all probability is the product of the growth of a single spore. BLACKMAN and FRASER (2) noted that the oogonium and antheridium are borne on the hyphae of separate origin in *Sphaerotheca Humuli* on Humulus. DANGEARD (6) noted that the male and female cells of Erysiphe arise from the separate hyphae and these hyphae may come from separate mycelia. As the result of experiments, in *Sphaerotheca fuliginea* on *Taraxacum ceratophorum*, it is seen that the ascogonium and antheridium are formed evidently on the ascogonial and antheridial hyphae originating from a single spore. In *Erysiphe Cichoracearum* on *Plantago major* var. *asiatica*, both sexual organs seem to be produced on the hyphae originating from the infection of the spores of two different strains.

In Erysiphaceae, there are two types of sexual process, the heterothallic and homothallic. The heterothallic species seem to be more common. The homothallic case is proved by the experiments to occur only in *Sphaerotheca fuliginea* on *Taraxacum ceratophorum*.

On the conjugation of the nuclei of the male and female organs, HARPER (14) recognized that fertilization occurs in Phyllactinia, Sphaerotheca and Erysiphe. A portion of the walls between the antheridium and oogonium is dissolved in such a fashion as to form a circular conjugation-pore leading from the antheridium to the oogonium. The protoplasm of the antheridial and oogonial cells is thus brought into direct contact and combines to form a continuous protoplasmic mass. The nucleus of the antheridium migrates through the conjugation-pore into the oogonium and approaches the egg nucleus. BLACKMAN and FRASER (2), and also BEZSSONOFF (1) have the same opinion as that of HARPER. According to DANGEARD (6), fertilization does not take place, the male nucleus degenerating in the antheridium. WINGE (47) supports this opinion. In 1931, WENTZEL (46) reported that no actual fertilization was observed. The writer recognized that the nucleus in the antheridium seems to have migrated into the ascogonium, as two, or rarely three, nuclei were found in the latter.

Asci and Ascospores

In the single-ascus group of Erysipheae, the ascus is subglobose in shape, and is generally larger than that of the many-asci group. The asci of the many-asci group are elongate-ellipsoidal or elongate-ovate in shape, and with or without a stalk. The ascus of Cystotheca is largest, and that of Erysiphe is smallest. The wall of an ascus generally becomes thin at the apex. The spores are ejected from this portion. The ascospores in an ascus are 2–8 in number.

Infection experiment. The perithecia on the affected leaves of *Taraxacum ceratophorum* which had been kept in the green house were collected in early March. Experiments on the germination of the ascospores were made in the laboratory every ten days. On July 5, the ascospores germinated. These ascospores were inoculated on the leaves of *Taraxacum ceratophorum* planted in pots, which had been covered with large glass tubes. On July 16, small white mycelial patches were observed on the inoculated portions. On the check plant, the mycelial hypae did not appear on the leaves. The mycelial patches increased in number by the secondary infection, and numerous conidia were produced. On July 22, young perithecia were produced on the first mycelial patch.

Hibernation

For the study on the hibernation of the perithecia, *Microsphaera alphitoides* on *Quercus crispula*, *Sawadaea Tulasnei* on *Acer pictum*, and *Sphaerotheca Humuli* on *Agrimonia pilosa* were kept in linen bags which were put in an open box planted in the ground in late autumn. The box was kept out of doors over winter. In early spring, when the materials were examined, numerous perithecia were found remaining on the host leaves, but matured asci could not be seen in any of them. The perithecia in a natural condition may lose their ascospores during winter when the affected leaves fall down on a moist soil.

In 1931, the pots of *Taraxacum ceratophorum* affected by *Sphaerotheca fuliginea* were carried into the green house in late autumn. Perithecia were abundantly produced on the leaves. In early March of the next year, several leaves were collected; one part was carried into the laboratory and the other part was put on the

soil in the green house. The ascospores in the former case germinated in the early summer, while in the latter, on which water had been poured every day, the ascospores seem to have been liberated earlier in the season.

The hibernation of *Sphaerotheca Mors-Uvae* parasitic on *Ribes grossularia* has been observed for several years. The perithecia on the leaves fall down with the leaves in winter, but those on the upper part of the shoots remain firmly attached till the next spring. Besides, a certain portion of the mycelia seems to hibernate between the scales of the buds.

The perithecial stage of *Sphaerotheca pannosa* on Rosa has not yet been collected in this country. Observations on its hibernation have been continued with interest for several years. In late autumn, the writer found the special mycelial masses on the shoots. A mycelium from such a mass was smooth, thick-walled and grayish in color, also it was composed of very long cells. In the next spring, although a careful observation was made on the changes of these masses, no new mycelial growth took place from them. New white mycelial patches appeared on the young leaves at the end of the shoot. The mycelial hyphae may probably have hibernated among the scales of the buds.

II. Host and Parasitism

A. Infection

For the studies of the infection process, wheat was generally used for the host and *Erysiphe graminis* f. sp. *Tritici* for its parasite. The following experiments were made in the green house of our University.

Experiment I

On the susceptible varieties of wheat

The seeds of *Triticum vulgare* (Sapporo Spring Wheat No. 9) were sown on moistened cotton in a large Petri-dish (diam. 15 cm.) on Feb. 8, 1927. On Feb. 15, the seedlings were inoculated on their coleoptiles with the conidia of *Erysiphe graminis* f. sp. *Tritici*. The next day, the inoculated portions were stripped off with a razor. The spore was found to have produced short germ-tubes 1–3 in number,

and some of the tubes produced a septum at their apical portion (Pl. VI, C, figs. 1, 2). After 3 days, the terminal portion of the germ-tube became enlarged and adhered to the surface of the leaf functioning as an appressorium (Pl. VI, C, fig. 3). On the 4th day, a roundish refractive body had been formed under the appressorium in the epidermal cell of the host plant (Pl. VI, C, fig. 4). This body is the primary stage of the haustorium. A minute hole was seen in the epidermal wall at the under-side of the appressorium. This hole shows the penetrated portion (Pl. VI, C, fig. 5). In a longitudinal hand section, one could see a protuberance inside of the epidermal wall at the place where the appressorium had been formed, and a very slender infection tube passing through its middle portion (Pl. VI, C, fig. 6). A globular body was formed at the terminal end of this tube. This is the primary haustorium. On Feb. 20, the globular incipient haustorium gradually became elongated (Pl. VI, C, fig. 7). On Feb. 23, the haustorium which has 3–5 finger-like branches on one or both sides was produced (Pl. VI, C, figs. 8, 9). The mycelial branches then began to grow from the appressoria and they formed mycelial hyphae creeping on the epidermis of the host plant.

The same experiments were repeated again on Feb. 23, 1932. They came to similar results, although the time of the formation of every part more or less differed.

The rest of the experiments were performed on wheat seedlings in which the inoculation was made on the green leaves. The materials 72 hours after inoculation were imbedded in paraffin by the usual method. The blocks were sectioned longitudinally at a thickness of 7μ. They were stained with the double staining of safranin and gentian-violet. The swollen portion of the epidermal wall was stained red in color, therefore, it could be easily distinguished from the other parts. The infection tube was readily found to be penetrating through its center. Numerous haustoria were often produced in an epidermal cell.

The epidermis of the same material was stripped off with a razor and stained with the same solution. The infected point of the epidermis stained light red in color in a circle of about 14.6 μ in diameter, and the other parts were violet in color (Pl. VI, C, fig. 10). The center of the circular patch was especially stained in deep red color, and a minute hole was seen at its middle portion.

The part of the epidermis which was in contact with the appressorium was at first stained in a light red color. In this stage, the

penetration of the infection tube was not yet seen. The reddish patch then gradually spread out and a deep red portion appeared in its center. This center is the swollen part of the epidermal wall. In this stage, it was found that the penetration of the infection tube began to take place in the epidermal wall. When a haustorium had reached its perfect development, the epidermis of the infected portion was stained violet in color.

The tips of the germ-tubes of the conidia were stained light red, and the red granules were found gathered in those parts.

FEHLING's solution was poured on the stripped epidermis of the affected leaf, and it was warmed with a gas flame for some minutes. The infection tube was found surrounded with a dense circular mass of small brown granules. Similar granules though few in number were found scattered in other parts. The same experiments were tried on the epidermis of a healthy leaf. The small brown granules were also found scattered in small numbers in the epidermal cells.

One and one-fourth percent HCl or Na (OH) was poured on the stripped epidermis of the diseased leaf and it was warmed as above described. The infection hole became enlarged to twice its diameter, showing that the cellulose portion of the epidermis was changed to soluble substances by enzymic action.

As the results of the above experiments, the mode of penetration of *Erysiphe graminis* f. sp. *Tritici* is considered as follows. The reserve materials in the matured conidia change to soluble substances and they are carried toward the apical portion of the germ-tube. These soluble substances may most likely be of the nature of soluble sugars, as in the case of the germination of seeds, in which the apex of the roots is always rich in soluble sugar and has an acid reaction. From the results of the reaction to FEHLING's solution, the presence of the reducing sugar is proved in the center of the infected spot of the epidermis, and that the infected patches are always acidic is proved by the staining reaction. From these facts, it is most likely that an enzyme is secreted from the under surface of the appressorium and from the infection tube, acting slowly on the cell wall of the epidermis. At first, the cell wall is changed to reducing sugar by the action of the cytase, and the reducing sugar thus produced immediately becomes changed to soluble sugar which permeates slowly to the substance of the cell wall in immediate con-

tact with the infection tube. In this stage, the reducing sugar reaction is not recognized and the presence of the soluble sugar is shown by the acid reaction. The infection tube penetrates through the center of the cellulose sheath. When the penetrating action attains a certain point, a part of the soluble sugar becomes reversed again to reducing sugar, when the sugar reaction can be recognized. After the haustorium is perfectly formed, the red patch in the cellulose sheath becomes gradually light in color and finally changes to a violet color similar to the rest of the cell wall.

Experiment II

On the immune varieties of wheat

Conidia from the affected leaves of *Triticum vulgare* were inoculated on the leaves of *T. dicoccum* var. *Khapli* on Feb. 12, 1932. After

Fig. 5. Showing the changes of epidermis of *Triticum dicoccum, Khapli,* after 48 hours from inoculation. (×550)

1. Stripped epidermis seen from above.
   a. Infection spot colored deep red.
   b. Roundish halo stained light red.

2. Longitudinal section.
   - a. Conidium.
   - b. Appressorium.
   - c. Point of infection.
   - d. A portion of epidermis stained deep red.
   - e. Epidermal cell.

3 days, several of the germ-tubes had already formed the appressoria and several others produced a septum at the apical portion of the tube. After 5 days, the mycelial branch began to be produced from the appressorium. At this time, a minute hole was seen on the epidermal wall under the appressorium. The pieces of the stripped epidermis were stained with safranin and gentian-violet. The epidermis was colored violet, but the infected portion was stained light red in a circular shape of about 22 μ in diameter, and at its center a space of about 6 μ in diameter was especially stained deep red. These changes in the epidermis are similar to those of the susceptible varieties.

After 48 and 72 hours from the inoculation, the pieces of the inoculated leaves were fixed and imbedded in paraffin. The blocks were sectioned longitudinally at a thickness of 8 μ, and were stained by the same method. In the present case, the infection tube was found penetrating part way into the center of the cellulose sheath, but it could not be seen that any had succeeded in passing through the sheath, nor was there even any formation of an incipient haustorium.

Experiment III

On several other plants

On Feb. 12, 1932, the conidia of *Erysiphe graminis* f. sp. *Tritici* were inoculated on the leaves of barley (Chevalier). After 48 hours, small pieces of the inoculated leaves were treated as in the previous cases. The mode of infection was found to be similar to the case of the immune varieties of wheat.

On Feb. 15, 1932, similar conidia were inoculated on the leaves of *Prunus communis* and *Plantago major* var. *asiatica*. After 48 hours, the epidermis of the inoculated parts was stripped off with a razor. The spores had produced one or two germ-tubes which had frequently formed a septum. The appressorium was found at the tip of the germ-tube. No further development took place.

On March 5, 1932, the inoculation experiments were made on *Plantago major* var. *asiatica* and *Acer pictum* with similar conidia. After 72 hours, small pieces of the inoculated leaves were imbedded in paraffin, after carrying though the ordinary process. The wall of the epidermis was stained violet and the reddish patches at the inoculated places could not be seen, moreover there was no observation of the cellulose sheaths in the epidermal cells just under the appressoria in both materials.

Summary as to the infection process

When the conidia of *Erysiphe graminis* f. sp. *Tritici* were inoculated on the immune and susceptible varieties of wheat, the infection tube produced from the appressorium of the germ-tube penetrated the cell wall of the epidermis in both varieties. In the susceptible varieties, the haustoria were quickly formed in the epidermal cells, while in the immune varieties, they were never produced. Also in barley, a process similar to that in the immune varieties of wheat was observed. According to SALMON (35), when the conidia formed on wheat were sown on barley, after 24 hours, the germ-tube produced an incipient haustorium; after 48 hours, some of the incipient haustoria began to be disorganized, while some one produced a vigorous haustorium; on the third day, the incipient or arrested haustoria became gradually disorganized; on the 5th day, nearly all the incipient haustoria showed complete arrest. In the present experiments, the author could neither observe the formation of the haustoria, nor even incipient haustoria, although the infection tube partly penetrated the wall of the epidermal cells. These different results may be caused by the biological characters of the conidia and the strains of the barley. In other plants which are distantly related to Gramineae, even the changes in the epidermal wall were not recognized.

B. Correlation of the development of the host plants to that of the powdery mildew

In the following experiments, the relation has been studied between the physiological condition of the host plants and the development of the powdery mildew. The physiological condition of the host plant can be divided for convenience into the following three stages in the development of its leaves.

Growing-stage—in this stage such leaves are included as from their youngest stage to the close of their growth. In the first half of this stage, their growth is most rapid, and in the latter half, much slower.

Matured-stage—growth is suspended and the leaves remain as they are. But in the first half, they may regain their growth as a result of favorable conditions of the environmental factors.

Senile-stage—in this stage the leaves become yellow in color from their tips and finally they turn yellowish brown.

1. Experiments with *Sphaerotheca fuliginea* parasitic on *Taraxacum ceratophorum*

Experiments A

These experiments were made to find the most favorable conditions of the host plant for infection by conidia.

I

On March 28, 1930 the seeds of *Taraxacum ceratophorum* were sown on moistened cotton in a Petri-dish (diam. 15 cm.). On April 7, the conidia of *Sphaerotheca fuliginea* were inoculated on each cotyledon with a needle. On April 9, the epidermis of the cotyledons was stripped with a razor, and examined. A small number of haustoria had already been produced. On April 26, the young perithecia appeared on the mycelial patches.

II

The Petri-dish was partitioned into four sections with glass strips and six seeds of *Taraxacum ceratophorum* were sown in each section at three days' intervals (Fig. 6).

The first sowing was made on May 11, as shown in the figure. On May 26, the seedlings in the four sections were inoculated

at the same time with the conidia. On May 30, the seedlings in the three sections (1, 2 and 3) were infected, but in section 4, the seedlings did not show any sign of infection until June 1.

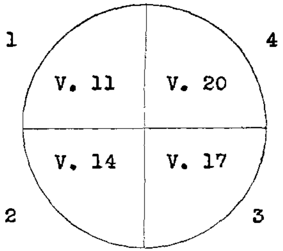


Fig. 6.

In experiments I and II, it was ascertained that the seedlings after about 7 days from germination began to be infected with the conidia.

III

On May 27, the leaves of three matured plants affected by the powdery mildew were all cut off except one central youngest leaf. On the same day, this youngest leaf was inoculated with the conidia, and each plant was covered with a large glass tube, whose upper opening was closed with a cotton plug. After three weeks, it was observed that infection had not taken place on any of these host plants. In field observations, it was also recognized that the youngest leaves in the rosette always remain unaffected until they reach a certain size.

IV

Two pots of the host plant which had been covered with the glass tube were put in a dark-box from April 16 to April 26, and

the lid of the box was opened for two minutes every day during the day time. On April 20, the leaves of the host plant turned greenish-yellow in color, and these etiolated leaves were then inoculated with the conidia. But the infected spots did not appear even after 10 days from the inoculation.

A similar experiment was repeated. During five days from June 9, two other pots were put into the dark-box without any exposure to sunlight. On June 13, the etiolated leaves were inoculated with numerous conidia, and the pots were kept in the same box until June 16, when they were carried out on to the bench of a green house. In this case also no infection took place, showing that the etiolated leaves are resistant to the attack of the powdery mildew.

V

On June 1, 2 cm. long pieces were cut off from the tips of the five unaffected leaves of the host plant, and each piece was placed on moistened filter paper in separate Petri-dishes. Conidia were immediately sown on the leaves. On June 5, haustoria were found in the epidermal cells of all the leaves, besides, even conidia were produced in a few cases in small numbers.

To state briefly the results of the above experiments; it was shown that *Taraxacum ceratophorum* was not infected in the earlier half of the growing-stage of its development with the conidia of *Sphaerotheca fuliginea*, nor in the latter half of the senile-stage. The most favorable conditions for infection by the conidia were found in the matured-stage of the development of the host plant.

Experiments B

These experiments were made to find the most favorable conditions of the host plant for the formation of perithecia by *Sphaerotheca fuliginea*.

I

Taraxacum ceratophorum which was used as the host plant, was covered with similar glass tube as in the former experiments. The pot was watered daily, so that the air in the tube was kept saturated with moisture.

a. Experiment by single spore inoculation

TABLE 2

Results of experiments of single spore inoculation of *Sphaerotheca fuliginea* on *Taraxacum ceratophorum* as to the time required for the formation of perithecia.

Experiment No.	Date of inoculation	Date of appearance of spot	Date of appearance of perithecia	Incubation period	No. of days from appearance of spot to perithecia formation
I	1930 X. 19	XI. 6	XII. 16	19	40
II	1930 XII. 26	I. 4	I. 10	10	7
III	1931 I. 14	I. 21		8	
IV	1931 I. 14	I. 25	II. 2	12	13

In No's. II and IV, the growth of the host was checked soon after inoculation; while in No's. I and III, the growth was continued, especially so in No. III. The powdery mildew parasitic on No's. II and IV made a rather poor growth. In those on No's. I and III, the mycelial patches continued their growth, and the conidia were abundantly produced. But in No. III, when the diameter of the mycelial patch attained about 1 cm. its growth was checked, and it gradually changed to grayish-brown in color and finally disappeared. The affected leaf in No. III thus regained its normal healthy condition.

b. The influence of the environmental factors on the formation of perithecia

TABLE 3

Results of inoculation experiments with *Sphaerotheca fuliginea* on *Taraxacum ceratophorum* plants which were placed in abnormal conditions.

Exp. No.	Physiological condition of the host	Date of inoculation	Date of appearance of spot	Experiments	Date of appearance of perithecia	No. of days from appearance of spot to formation of perithecia
I	Good	IV. 6	IV. 13	Control	No formation of perithecia	—
II	Poor	IV. 6	IV. 16	Host plant was put in dark-box from IV. 16	IV. 30	14
III	Good	IV. 6	IV. 12	Host plant was put in dark-box from IV. 13	IV. 17	5
IV	Moderate	IV. 6	IV. 13	On IV. 16, midrib was wounded with needle	IV. 19	6
V	Good	IV. 26	V. 3	On V. 7, host plant was carried into glass house	V. 10	7
VI	Good	IV. 26	V. 2	On V. 27, host plant was withered	V. 29	27

As shown in the above table, on April 6, the host plants No's. I to IV were inoculated on the leaves with the conidia. After the spots had appeared on each plant, the experiments were begun.

No. I was left as a control under normal conditions. From the start, the host plant was in an excellent condition, and conidia were abundantly produced. After about two weeks, the mycelial patches began to disappear, and the affected leaves regained the normal healthy condition.

In No. II, the host plant was exposed to sun-light for two hours every day, and for the rest of the time it was put in the dark-box. As a result, the host plant was retarded in growth. This experiment was continued for 11 days, but perithecia were not formed during that time. On April 27, the pot was brought out of the box and placed on the bench of the green house. On April 30, when the condition of the host plant was somewhat recuperated small perithecia began to appear.

In No. III, an experiment similar to No. II was repeated from April 13. The leaves of the host plant continued to grow for about 3 days after being placed in the dark-box. In this case, conidia were abundantly produced. Later, the development of the host plant was retarded. On April 17, perithecia began to appear on the patch of mycelila.

In No. IV, the host plant had been in a moderately good condition. On April 16, the midrib of the affected leaf was wounded with a needle. On April 19, small perithecia were found.

In No's. V and VI, the hosts were inoculated with conidia on April 26. In No. V, the host plant and its powdery mildew were in good condition. On May 7, the plant was transferred to a glass house of about 12°C. from the green house. On May 10, perithecia were produced.

In No. VI, host plant and its powdery mildew were in similar condition as in No. V. Perithecia were not formed even after three weeks from the time of inoculation. On May 27, the glass tube was taken away from 1 p.m. to 2 p.m., when the host plant became withered from the excess of transpiration. The next morning, it regained the normal conditions. On May 29, the perithecia appeared.

In the above experiments, attempts were made to ascertain the influence of light, temperature and moisture on the formation of perithecia. The interception of the light has been thought to accelerate the formation of perithecia, but this holds true only after the affected host plant has changed from its matured-stage to the first half of its senile-stage. When a host plant in the matured-stage is placed in the dark-box, events take three different courses of development. In the first course, the host plant soon begins to renew its growth returning to the growing-stage, when perithecia formation does not take place; in the second one, its physiological condition is decreased to minimum, when perithecia formation also does not take

place; and in the third one, the host plant gradually enters senility and only in this case does perithecia formation take place. When the host plant is affected by a wound, unfavorable temperature or drought, the change in its physiological condition thus brought about causes similar results as in the case of the use of the dark-box.

c. Experiment with cut leaves

The tips of ten healthy leaves of the host plant were cut off in 2 cm. lengths, and each piece was placed on moistened filter paper in a Petri-dish. The cut end was covered with moistened cotton.

TABLE 4

Results of inoculation experiments with *Sphaerotheca fuliginea* on cut leaves of *Taraxacum ceratophorum* which were placed under abnormal conditions.

Exp. No.	Date of inoculation	Date of infection	Experiment	Observation on VI. 8
I II	VI. 1	VI. 3 "	Control, left in laboratory near the window	Conidia produced in small quantity
III IV	"	VI. 3 VI. 4	Petri-dish was brought into glass-house (13°C.) on VI. 5	Conidia produced abundantly
V VI	"	VI. 3 VI. 4	Petri-dish was put in dark-box from VI. 5, and exposed to sunlight for several minutes every day	Conidia not produced
VII VIII	"	VI. 4 "	Petri-dish was put in dark-box from VI. 5 to VI. 7, without exposing to sunlight	Mycelial spot disappeared
IX X	"	VI. 4 "	On VI. 5, midrib was wounded with needle ; then left in laboratory as in control	Conidia produced abundantly

All the leaves were changed to yellowish green in color on June 10, especially so in the leaves which were kept in the dark-box, and the perithecia were not produced on every leaf.

Summary of Series I Experiments

When affected plants of *Taraxacum ceratophorum* in the stage of late maturity growing in air of saturated humidity were placed in checked sunlight, or in a room of lower temperature, or were affected by a wound or by wilting, the formation of perithecia took place. But when the affected plants in the growing-stage were placed under similar conditions, perithecia were never produced. When those belonging to the stage of early maturity were placed under similar cnditions, the result was either positive or negative. If the plants begin to renew their growth returning to the growing-stage or if their physiological condition is suddenly caused to become very bad, perithecia formation does not take place. But, if they are gradually changed to the senile-stage, the perithecia formation takes place.

II

The following experiments were made on the bench of a green house; the host plant was not protected with a glass cover.

TABLE 5

Results of inoculation experiments with *Sphaerotheca fuliginea* on *Taraxacum ceratophorum* plants which were placed in dark-box or were wounded.

Exp. No.	Date of inoculation	Date of infection	Physiological condition of the host plant 3 days after infection	Experiment	Date of appearance of perithecia	No. of days from infection to formation of perithecia
I	V. 11	V. 14	Poor	Control	V. 22	9
II	,,	V. 15	,,	On V. 18 midrib of the leaves was wounded with needle	V. 21	7
III	,,	V. 15	,,		V. 19	5
IV	,,	V. 15	,,	Host plant was put in dark-box for 48 hours from V. 19	V. 21	7
V	,,	V. 15	,,		V. 24	10

Each plant of the five pots showed a poor physiological condition. The midrib of certain leaves of No's. II and III was wounded with a needle. No's. IV and V without wounding were kept in the dark-box for 48 hours. In No's. II, III and IV, the perithecia formation occurred sooner than in the case of the control. In No. V, the host plant and its powdery mildew were induced to grow by the interception of sunlight for two days. The formation of perithecia was more or less retarded by this abnormal growth.

TABLE 6

Results of the inoculation experiments with *Sphaerotheca fuliginea* on *Taraxacum ceratophorum* plants which were placed in the dark-box of different temperatures.

Exp. No.	Date of inoculation	Date of infection	Physiological condition of the host plant 3 days after infection	Experiment	Date of formation of perithecia	No. of days from infection to formation of perithecia
VI	V. 27	V. 30	Poor	Control	VI. 8	10
VII	,,	V. 29	Fair	Host plant was put in dark-box at room temperature	VI. 6	9
VIII	,,	V. 29	,,		VI. 3	6
IX	,,	VI. 1	Poor	Host plant was put in dark-box in green house	VI. 7	7
X	,,	V. 29	,,		VI. 8	11

On May 27, conidia were inoculated on the leaves of all the host plants. In this experiment, an attempt was made to show the influence of temperature on the formation of perithecia. The plants in No's. VII and VIII were placed in the dark-box at room temperature, and were exposed daily to sunlight for 3 hours from midday to 3 p. m. The temperature of the dark-box was as follows:

Date	Temperature: When the pot was brought out from the dark-box	Temperature: When the pot was kept in the dark-box
VI. 1	—	14°
,, 2	12°	12
,, 3	12	12
,, 4	14	14
,, 5	11	10
,, 6	12	—

In No. VII, the host plant continued abnormal growth for about 3 days after being placed in the dark-box, then the growth was retarded from about June 4, and on June 6, young perithecia appeared. In No. VIII, when the pot was put in the dark-box, the host plant was retarded in growth. Perithecia were more quickly produced than in the case of No. VII.

In No's. IX and X, the hosts were placed in the dark-box of the green house from June 4, and were exposed to sunlight for 3 hours every day. The temperature of this box was as follows:

Date	Temperature: When the pot was brought out from the dark-box	Temperature: When the pot was kept in the dark-box
VI. 4	—	20°
,, 5	14°	14
,, 6	16	15
,, 7	17	16
,, 8	20	—

The host plants were placed on the bench of the green house from the date of infection to June 4, that they might improve their physiological condition as they were much weakened. After they were placed in the dark-box, young perithecia were produced in 4 or 5 days.

TABLE 7

Results of the experiments on the influence of wilting on the formation of perithecia.

Exp. No.	Date of inoculation	Date of infection	Growth of mycelia 3 days after infection	Experiment	Date of formation of perithecia	No. of days from infection to formation of perithecia
XI	VI. 13	VI. 18	Poor	Control	VI. 25	8
XII	,,	VI. 17	Good	The pot dried in green house	VI. 22	6
XIII	,,	VI. 16	Good	,,	VI. 22	7
XIV	,,	VI. 18	Poor	The pot dried out of doors	VI. 26	9
XV	,,	VI. 17	Poor	,,	VI. 26	10

The above experiments were carried out to study the influence of wilting on the formation of perithecia. In No's. XII and XIII, the pots were not watered until the leaves had drooped to the surface of the soil. In No's. XIV and XV, similar experiments were carried on out of doors, and the condition of these plants was more vigorous than that of the plants placed in the green house.

When the apical portion of the leaves of the plants under observation became yellowish green in color, the perithecia began to be formed. That is to say, when the host plant began to enter the first stage of senility in its development, the perithecia formation would begin to take place.

From the experiments of series II, the same conclusions are drawn as from series I.

2. Experiments with *Erysiphe Cichoracearum* parasitic on *Plantago major* var. *asiatica*.

In Oct. 1930, ten pots of *Plantago major* var. *asiatica* were transferred to the green house and three of them were inoculated with the conidia of *Erysiphe Cichoracearum* formed on the leaves of a host plant of the same species growing out of doors. In late November,

perithecia appeared on those leaves. The conidia formed on these host plants were used in the following experiments.

Experiments A

These experiments were made to find the most favorable condition of the host plant for infection of conidia.

I

On Aug. 6, 1931, the old matured leaves of the plants growing in six pots were cut off leaving only two or three young leaves behind, and conidia were immediately inoculated on these leaves. No plants were infected.

On Aug. 11, a similar experiment was repeated on leaves from two other potted plants. The infection was again unsuccessful.

II

Two plants were put into the dark-box on Feb. 18, 1932; they were exposed to the sunlight for one minute every day. On Feb. 23, when their leaves became etiolated turning greenish yellow in color, they were inoculated with conidia, and were kept continually in the same condition. They were not infected.

On March 12, the etiolated leaves of the plant kept in the dark-box were inoculated with conidia. In this case, they were also not infected. The vital condition of the etiolated leaf may be similar to that of the latter half of the senile-stage.

III

Two pots of *Plantago major* var. *asiatica* were placed on the bench out of doors. On Nov. 10, 1932, the old leaves turning red in color were inoculated with conidia. This inoculation was also unsuccessful in infection.

As the result of the above 3 experiments, *Plantago major* var. *asiatica* may be said to be non-infectable in the earlier half of the growing-stage and in the latter half of the senile-stage.

Experiments B

These experiments were made to find the most favorable condition of the host plant for the development of *Erysiphe Cichoracearum*.

I

a. Experiment by single spore inoculation

In the single spore inoculation, the same method was employed as in the case of *Sphaerotheca fuliginea*, and each plant was covered with a large glass tube. This experiment was carried on in the green house, and seedlings were used as the host plant.

TABLE 8

Results of the inoculation experiments of single spore inoculation with *Erysiphe Cichoracearum* on seedlings of *Plantago major* var. *asiatica*.

Exp. No.	Date of inoculation	Date of infection	Results
I	X. 22, 1932	X. 30, 1932	A month after infection host plant withered, without producing perithecia
II	,,	Not infected	
III	,,	X. 29	About II. 18, 1933 infected leaves withered, without producing perithecia
IV	,,	Not infected	
V	,,	,,	
VI	XI. 6	,,	
VII	,,	,,	
VIII	,,	,,	
IX	,,	,,	
X	,,	XI. 17	3 weeks after infection host plant withered without producing perithecia
XI	XI. 14	XI. 21	Host plant was in vigorous condition, but perithecia were not produced
XII	,,	XII. 3	
XIII	,,	XI. 21	

In the following experiments, the pots from No. I to No. XV were put out of doors, and those from No. XVI to No. XXIV were placed in the green house. Matured plants were used as the host.

TABLE 9

Results of single spore inoculation experiments with *Erysiphe Cichoracearum* on matured plants of *Plantago major* var. *asiatica*.

Exp. No.	Date of inoculation	Date of infection	Results
I	VII. 2, 1932	Not infected	
II	,,	,,	
III	,,	,,	
IV	,,	,,	
V	,,	,,	
VI	VIII. 11	,,	
VII	,,	,,	
VIII	,,	,,	
IX	,,	,,	
X	,,	,,	
XI	IX. 5	,,	
XII	,,	,,	
XIII	,,	,,	
XIV	,,	,,	
XV	,,	,,	
XVI	X. 26	XI. 2, 1932	On II. 15, 1933, the host plant was still in vigorous condition, but perithecia had not been produced
XVII	,,	Not infected	
XVIII	,,	,,	
XIX	,,	XI. 2	On II. 15, host plant was in weakened condition, and perithecia had not been produced
XX	,,	Not infected	
XXI	XI. 8	,,	
XXII	,,	,,	
XXIII	,,	,,	
XXIV	,,	XI. 14	On II. 15, host plant was in vigorous condition, but perithecia had not been prodnced

Among nine infected plants, No's. XI, XII, XIII of Table 8 and No's. XVI and XXIV of Table 9 were in vigorous vital condition. They had progressed from the growing-stage to the matured-stage and reached the senile-stage in the green house within about foui

months after the time of the infection. The perithecia were not produced on any of these infected plants. On the stock plant, the young perithecia had appeared in the open air in Oct. 1932. Perhaps, the form on *Plantago major* may belong to the heterothallic species.

b. Experiments by inoculation with many spores

In this experiment, the host plants were covered with large glass tubes.

In Sept. 25, 1933, leaves of potted mature *Plantago major* were inoculated with many spores. The stock plant was placed side by side with the infected in pots in the green house without cover. Perithecia appeared on the stock plant on Oct. 25. Some of the inoculated plants pots were infected on Oct. 5, but did not produce perithecia until December, for the host plants always remained in the previously attained stage of maturity.

Similar inoculation experiments were repeated on five additional pots:

	Date of inoculation	Date of infection
I	XI. 6	Not infected
II	XI. 16	XI. 22
III	XI. 18	XI. 23
IV	XI. 18	Not infected
V	XI. 18	XI. 22

The leaves of the infected plants continued vigorous growth under the influence of temperature and moisture in the large glass tubes. The mycelial patches began to disappear on Feb. 10, 1934, and finally the mycelial hyphae could not be seen on the leaves, although the yellowish green spots still remained. In the glass tubes the vital condition changed slowly and the plants did not reach the senile-stage before the mycelial patches disappeared.

In the above experiments, the reason why the perithecia were not produced may be that the plants were in unfavorable vital condition for the development of the parasite.

II

The following experiments were carried out in the green house; the host plant was not protected with a glass cover.

TABLE 10

Results of the inoculation experiments with *Erysiphe Cichoracearum* on *Plantago major* var. *asiatica* which was placed in the dark-box at different temperatures.

Exp. No.	Date of inoculation	Date of infection	Experiments
I II	II. 22, 1932 ,,	II. 24, 1932 II. 25	Control. On No. I, perithecia were not produced, while on No. II, they were produced in Oct.
III IV	,, ,,	II. 25 ,,	Host plant was kept in dark-box in green house from IV. 1 to IV. 3. Perithecia were not produced
V VI	,, ,,	II. 24 ,,	Host plant was kept in dark-box in glass house from IV. 1 to IV. 3. In Oct. perithecia were produced on No. V, while on No. VI, they were not produced

After infection, all host plants were at first carefully taken care of in the green house. The vital condition of the host plants was more or less weakened as they had been kept in the dark-box. But perithecia were not produced on them through the summer. In October, perithecia were found on the matured leaves of No's II and V.

The experiment was repeated.

TABLE 11

Results of the inoculation experiments similar to the foregoing ones.

Exp. No.	Physiological condition of host plant	Experiments
I	Good	Control. Perithecia were not produced
II	,,	Host plant was kept in dark-box in green house. Perithecia were not produced after two months from inoculation
III	Poor	,,
IV	Moderate	Host plant was kept in dark-box in glass house. Perithecia were not produced after two months from inoculation

The control was kept continually on the bench of the green house. On Nov. 28, 1932, No's. II and III were put into the dark-box of the green house and were exposed to sunlight from midday to 2 p. m. every day. In No. IV, a similar experiment was carried out in the glass house instead of the green house. Perithecia were not produced in any cases.

The temperatures in the boxes placed in the green house and also in the glass-house were as follows:—

Date	When the pot was brought out from dark-box of green house	When the pot was put into dark-box of green house	When the pot was brought out from dark-box of glass house	When the pot was put into dark-box of glass house
XI. 28	—	29°	—	10°
,, 29	26°	23	8.5°	9.5
,, 30	25	23	8.5	8
XII. 1	29	31	10	11
,, 2	26	21	9	7
,, 3	28.5	29.5	8.5	8.5
,, 4	31	29	9.5	9
,, 5	29	30.5	8	9.5
,, 6	29	23	9	9
,, 7	26	—	8	—
,, 8	—	30	—	10
,, 9	27	—	9	—

On Dec. 9, after 12 days' inclosure in the dark-box, the leaves of the host plants turned yellowish green in color. In No's. II and III the pots were then brought out from the dark-boxes to the bench of the green house and in No. IV to the glass house to regain their normal condition. The perithecia could not be found on those leaves after two months.

The following facts may be set down as the results of the two series of experiments B. In the leaves of the host plants in experiment I, the senile-stage was very short while the growing-stage was long as they were covered with large glass tubes. Mycelial hyphae and conidia were abundantly produced on the leaves, but perithecia did not appear on any plants. In experiment I, a, by a single spore inoculation, perithecia were not produced on the leaves although the host plant was matured, showing that the fungus is most likely heterothallic in character. In experiment I, b, using inoculation with many

spores, when the leaves had reached the most vigorous growing-stage, the mycelial hyphae were checked in growth and began to disappear.

In experiment II, in which the plants were not covered with glass tubes, and they were inoculated with many spores, the perithecia formation did not quickly take place. The perithecia were formed on the leaves which had reached the stage of senility, eight months after the infection.

3. Experiments on *Erysiphe graminis* parasitic on wheat

Experiment *A*

When the inoculation experiments were made on the several species and strains of wheat with the conidia of *Erysiphe graminis* f. sp. *Tritici*, the infection did not take place in the early young stage of the host.

The following experiments were made for the purpose of finding the most favorable stage of the host plant for the infection.

The seeds of *Triticum turgidum* were sown in six pots at three days' intervals from Jan. 7. These pots were placed in the green house side by side with affected *Triticum Spelta* and they were left to induce the natural infection. The results of the experiments are shown in the following table.

TABLE 12

Results of the inoculation experiments of *Erysiphe graminis* on the seedlings of *Triticum turgidum* which were sown at three days' intervals and left to induce natural infection.

Host	Date of sowing	Date of infection	No. of days from sowing to infection
Triticum turgidum	I. 7	I. 31	25
,,	I. 10	II. 3	25
,,	I. 13	II. 9	28
,,	I. 16	Not infected	
,,	I. 19	II. 15	28
,,	I. 22	II. 17	27

According to the experimental results shown in above table, the infection did not occur at the same time on the host plant of the different stages. In this case, the infection did not occur unless the host had passed about three weeks from the time of sowing. The conidia were produced on the second or third day after the appearance of the spot. Such phenomena were observed in every case on the first, second and third leaves and so on consecutively.

In July, 1931 *Triticum turgidum* planted in the pot reached the flowering stage. At this time, the plants were inoculated with numerous conidia. The uppermost leaf was infected after a week from the inoculation, but spots did not appear on the fully matured leaves on the same stalk.

Experiment B

In these experiments, the author observed on the relation of the incubation period and the physiological condition of the host plant.

I

The seeds of *Triticum turgidum* were laid on moistened filter paper in the large Petri-dish which was then placed in the green house at 14°–28°C. Three days later (Jan. 14), the seedlings grew to about 1 cm. in length. Then the seed was removed from the seedling which was quickly sterilized with 50% alcohol, and transferred to a test tube containing about 15 cc. of 2% sterilized agar. On Jan. 16, the conidia were inoculated on the first leaf with a sterilized platinum needle. On Jan. 25, newly formed conidia became visible on the surface of the inoculated leaf. In this experiment, the incubation period was 10 days. When the conidia were inoculated on the normal leaf, the incubation period was 3 or 5 days.

II

On Jan. 27, the seeds of *Triticum turgidum* were sown on moistened filter paper in a Petri-dish as in the former experiment. The cotyledonous leaves were inoculated with conidia on Jan. 31. After 24 hours, the epidermis was stripped off with a razor and was

observed. It was found that almost all the conidia had germinated, but no infection had taken place. On Feb. 20, conidia were formed on the leaves of the host plant and many haustoria were produced. In this case, it is shown that the infection took place within 3 weeks from the time of inoculation.

III

The following experiments were made for the purpose of studying the development of the conidia inoculated on the leaves which are in a physiological condition unfavorable for infection.

On Feb. 10, seeds of *Triticum turgidum* were sown in a large Petri-dish, and after 4 days, these seedlings were transferred to test tubes as in experiment I. The cotyledonous leaves were inoculated with conidia on the next day. After 24 hours, the seedling was drawn out from the tube and the epidermis of the inoculated portion was stripped off with a razor. Small germ tubes were produced from the conidia. After 2 days from the inoculation, the germ tubes became gradually elongated and swollen up a little at their apices, whose contents presented a dense granular appearance. After 3 days, an appressorium was produced at the apex of the germ tube, but no penetration tube was yet produced. After 5 days, the appressorium firmly adhered to the surface of the epidermis and began to penetrate into the epidermal cell by sending out an infection tube. After 7 days, the infection tube penetrated into the epidermal cell and produced a globular vesicle containing granules. After 10 days, many finger-shaped haustoria were produced in the epidermal cells and young conidia were formed on the surface of the leaves.

By the above experiment, it was shown that for the penetration of the infection tube into the epidermal cell about 6 days were needed.

Seeds of *Triticum monococcum* var. *vulgare* and *T. dicoccum* var. *farum* were sown in pots on Oct. 19, 1931. On Nov. 10, the plants were inoculated with conidia from on *T. Spelta*. They were readily infected, but after a month, the affected leaves withered, and the host plant continued healthy growth. On Feb. 23, 1932, spores from on *T. Spelta* were abundantly sprayed on the leaves of both species, kept in green house. This experiment ended with a negative result. The leaves were too fully matured for infection.

Summary of Experiments on *Erysiphe graminis*

Up to the present time, reports have been published by several authors on the incubation period for infection of *Erysiphe graminis*. E. W. NEGER (24) recorded that from the time of the inoculation of the conidia to the production of the conidiophores it took 2 to 4 days, but the incubation period varies with the environmental factors as temperature, moisture and season. E. S. SALMON (35) remarked that the incubation period required 4 days under normal conditions and sometimes 5 days or even longer. The writer agrees that the period of incubation is varied by the influence of the environmental factors. Besides, when the host plants are in the different growing stages, the infection does not occur at the same time, although they are placed under almost similar conditions. Even in one and the same wheat plant, the spots do not appear at the same time on all leaves, but they are produced in order from below upwards. When the leaves reach the latter half of the growing-stage, they are infected quickly, and in this case, the incubation period is the shortest.

On the other hand, when the leaf reaches the senile-stage, the infection never takes place.

4. Experiments with *Microsphaera Alni* parasitic on *Picrasma quassioides, Sawadaea Tulasnei* on *Acer pictum*, and *Podosphaera tridactyla* on *Prunus triflora*.

In Aug. 1931, several pots of *Picrasma quassioides, Acer pictum,* and *Prunus triflora* were transferred to green house. Some of them were inoculated with conidia of *Microsphaera Alni, Sawadaea Tulasnei,* and *Podosphaera tridactyla*. The experiments of single spore inoculation were repeated again and again from 1931 to 1933, but unfortunately the plants were never infected. Perithecia were produced, however, on the stock plants in November.

Sawadaea Tulasnei on *Acer pictum* is noteworthy for the fact, that two forms of conidia, the micro- and the macro-, are produced in this species. In nature the macro-conidia begin to appear in early July, and the micro-conidia in late August. Two pots of

Acer pictum were inoculated with macro-conidia on Sept. 11. The infected spots appeared on both plants on Sept. 23 and 26. On this occasion, the macro-conidia were at first produced. Later, the micro-conidia appeared on the same mycelial patches of both plants on Oct. 3 and 7. It was determined under microscope that the macro- and micro-conidia were formed on the same mycelium. Perithecia were produced on both plants on Oct. 27 and 19. In this species, it seems to be necessary for the fungus to pass the micro-conidial stage in order for the perithecia formation to occur. The incubation period of this species was longer than that of the powdery mildews on the grasses.

5. Experiments with *Phyllactinia imperialis* parasitic on *Paulownia tomentosa*

On Sept. 26, 1931, two young plants of *Paulownia tomentosa* about 30 cm. in height were inoculated with conidia from a host plant of the same species growing in nature, and they were put in the green house. On Oct. 8, both plants were infected, and on Oct. 23, perithecia appeared on each leaf.

On Oct. 3, conidia were inoculated on the plants in other pots, and perithecia were produced on matured leaves after a month. But, on young leaves, the conidia only were produced. Later, the old affected leaves fell down without producing any perithecia. The natural infection by conidia took place on the young leaves, but perithecia were not produced on them, although they were put into a dark-box or caused to wither or were wounded. The old mycelial hyphae turned brown in color from the center of the white patches.

6. Field observation

Field observations on the relation between the host plants and powdery mildew are recorded in the following notes.

Erysiphe Galeopsidis on *Lamium album* var. *barbatum* appears in late June in nature in the vicinity of Sapporo, and perithecia are produced in the middle of summer. *Lamium album* var. *barbatum* sprouting in the very early spring, in early July plants attain the

flowering stage, and in middle summer they gradually enter the senile-stage, when the perithecia are formed on the leaves.

Podosphaera leucotricha on *Malus baccata* var. *mandshurica* attacks its sprouts in late May. Some sprouts wither from its attack, but some others continue their growth. Conidia are abundantly produced in the latter case, and a small number of perithecia are formed in November. Generally, when hyperplasia is induced on the host plants by the stimuli of the powdery mildew, the perithecia formation is always retarded. This is probably due to the vital condition of the host plant which is restored to the growing-stage by an abnormal growth. *Sphaerotheca pannosa* on Rosa, and *Sph. Epilobii* on Epilobium belong to this category too.

When Erysiphaceae attacked the shoot, as for example, in the cases of *Podosphaera leucotricha* on *Malus pumila* var. *domestica*, *Sphaerotheca pannosa* on Rosa, *Microsphaera alphitoides* on Quercus, *Sawadaea Tulasnei* on Acer, and *Sphaerotheca Mors-Uvae* on Ribes, the apical part of the growing shoot is not always affected.

Also in the rust-fungi, when the sporidia are sprayed on the shoots of thir hosts, the sori are not formed on the apical part of the sprout. Similar cases are observed in Peronospora on *Stellaria media*, *Papaver somniferum*, *Spinacia oleracea*, etc. Two or three leaves on the upper part of the sprout were not always affected, although all other leaves were infected. It will be recognized that the results of the field observations and of the experiments entirely agree.

Summary of the results obtained in the experiments on the correlation between the developments of the host plant and the powdery mildew.

The physiological condition of the host plant could be treated as of three stages, growing, matured and senile. In the first half of the growing-stage and the second half of the senile-stage, the infection of the conidia and the mycelia growth did not take place. The most favorable condition for mycelia growth and conidia formation is found in the matured-stage, and that for the perithecia formation is in the stage of early senility. Perithecia formation is found only on the host plants which have made their full growth. The late

maturity stage and early senility stage seem to be abridged or absent in the green house. The three stages of the host plants are influenced by environmental factors.

On the relation between the several species of the powdery mildew and certain environmental factors, viz., sunlight, temperature, and humidity, many experiments have been tried.

In 1914, G. M. REED (29) studied the influence of light on the infection of barley and wheat by the powdery mildew. The seedlings of barley and wheat which have been grown in the dark until the first leaf was about 2 to 3 cm. long, were inoculated with conidia of powdery mildew. Some of the plants which had been kept continuously in the dark were not infected. Also, on the seedlings which had been grown in the light, when they were kept continuously in the dark after the inoculation, no infection occurred. The effect upon the mildew of the absence of light is considered to be an indirect one and has to do with the primary effect upon the development of chlorophyll in the host cells.

In 1930, F. LAIBACH (21) noted that the influence of the sunlight on the conjugation of the sexual cells is very slight, because on *Lamium album* and *L. purpureum*, the perithecia are abundantly produced in mid-summer or in the green house in winter. The perithecia formation is also not distinctly influenced by the temperature. According to the results of his experiments carried out in different rooms of 3°–7°, 10°–12° and 18°–20°, in the low temperature room, 3°–7°, the incubation period was longer than in the other rooms, nevertheless the formation of perithecia took place in all rooms. The influence of high humidity on the vital function of the fungus is felt directly or indirectly through that of the host plant.

In the results of the above described experiments, checking the sunlight did not promote the formation of perithecia or the growth of mycelia, but when the host plants happened to grow vigorously, the perithecia formation was checked, and the growth of mycelia was increased. When the affected hosts were etiolated, the powdery mildew gradually disappeared. In the etiolated condition, the host plants could not be infected with conidia. The influence of temperature and moisture was similar to that of sunlight.

In the experiments on the influence of such factors as light, temperature, and humidity it is extremely difficult to distinguish

the direct influence of those factors on the parasites themselves from their indirect action on the host plants.

III. Specialization and Resistance

For the purpose of determining the specialization of a powdery mildew in its relation to the resistance of its host plant, the following experiments have been made. Wheat was used as the host plant, and *Erysiphe graminis* DC. f. sp. *Tritici* MARCHAL was chosen as the parasite. This fungus is one of the seven specialized forms of *Erysiphe graminis* established by E. MARCHAL in 1902. In 1933, E. B. MAINS (17) reported two physiologic forms in *Erysiphe graminis* f. sp. *Tritici*. Axminister and Norka are resistant to form 1, while they are heavily infected by form 2. The fungus used in the present experiments was not tested to determine which form it belongs to.

1. Infection experiments with the conidia

In wheat, resistance and susceptibility to the powdery mildew have been hitherto studied by several authors.

In 1902, E. MARCHAL (23) remarked that *Triticum vulgare*, *T. Spelta*, *T. polonicum* and *T. turgidum* are susceptible species, while *T. durum*, *T. monococcum* and *T. dicoccum* are resistant.

In 1903, E. S. SALMON (33) reported that *Triticum vulgare* and *T. Spelta* were readily infected by the conidia on *T. vulgare*. He also studied the adaptation of parasitism in *Erysiphe graminis* parasitic on the species of Bromus and found the presence of the bridging species among certain species of the brome-grass.

In 1913, N. I. VAVILOV (43) reported observations on the field conditions. Thirty varieties of *Triticum vulgare*, 7 varieties of *T. compactum*, and 9 varieties of *T. Spelta* were found to be susceptible, while 10 varieties of *T. turgidum*, 15 varieties of *T. durum*, 3 varieties of *T. polonicum*, and 4 varieties of *T. monococcum* were determined to be resistant. Five varieties of *T. dicoccum* were proved to be either highly susceptible or resistant. In 1914, the same author

(44) noted that *T. vulgare* (with the exception of a few races), *T. compactum*, and *T. Spelta* belong to the susceptible hosts, while *T. durum*, *T. polonicum*, *T. turgidum*, and *T. monococcum* to the resistant. *T. dicoccum* has both susceptible and immune races. In 1918, the same author (45) reported that *Triticum sativum* in a broad sense is attacked by *Erysiphe graminis* f. *Tritici*, while some varieties of *T. dicoccum* are absolutely immune.

In 1909, 1912, 1916, and 1918, one hundred and sixty-one varieties belonging to the eight recognized types or species of Triticum were tested on the resistant character to *Erysiphe graminis* under green house conditions by G. M. REED (27, 28, 30, 31). The great majority of these varieties were highly susceptible to the wheat powdery mildew. It may be specially noted that *T. dicoccoides* KCKE., the wild wheat of Palestine, proved to be quite susceptible. In the distinctly resistant varieties are included *T. dicoccum* var. *Khapli*, *Russian Emmer* and *Spring Emmer*, and *T. vulgare* var. *caesium* and *pyrothrix*.

REED also tested various other species of Triticum, and *T. bicorne* and *T. caudatum* proved to be highly susceptible, while *T. triaristatum* and *T. triuncinale* proved to be resistant.

According to the papers above cited, in *Triticum polonicum* and *T. turgidum*, both lines of resistant and susceptible varieties seem to be included. Also, in *T. dicoccum* and *T. vulgare*, both varieties of distinctly susceptible and highly resistant characters are included. We have come to recognize that the degree of the susceptibility and resistance in different varieties of wheat to the infection by *Erysiphe graminis* f. sp. *Tritici* can not be stated in general terms.

Experiment 1

In the spring of 1922, many varieties of wheat, which were sent from Dr. D. FAIRCHILD, Bureau of Plant Industry, U. S. Department of Agriculture to Prof. K. MIYABE, were sown in the field of our University, and left to the natural infection. The degree of the infection caused by the powdery mildew is shown in the following table.

TABLE 13

Results of the natural infection of *Erysiphe graminis* on wheat sent from the Bureau of Plant Industry, U. S. Department of Agriculture.

Exp. No.	Varieties of wheat	Degree of infection	
		1922, VII. 20	1922, VIII. 1
1	Marquis (T. vulgare var. lutescens)	1	1
2	Little Club (T. compactum var. Humboldtii)	3	4
3	Haynes	1	1
4	Federation (T. vulgare var. alborubrum)	4	4
5	Kota	3	2
6	Pacific Bluestem	3	3
7	Early Baart (T. vulgare var. graecum)	1	2
8	Preston (T. vulgare var. erythrospermum)	0	0
9	Kanred	0	0
10	Turkey (T. turgidum var. iodurum)	0	0
11	Mammoth Red (T. vulgare var. erythrospermum)	0	0
12	Dawson's Golden Chaff (T. vulgare var. alborubrum)	0	0
13	Fulcaster	0	0
14	Poole (T. vulgare var. milturum)	0	0
15	Purple Straw (T. vulgare var. lutescens)	0	0
16	Pentad	0	0
17	Hybrid 128	0	0
18	Acme	0	0
19	Kubanka (T. durum var. hordeiforme)	0	0
20	Monad	0	0

Note, 0 = infection spots did not appear; 1 = infection spots appeared in minimum quantity; 4 = infection spots appeared in maximum quantity; 2 and 3 = infection spots in intermediate quantity.

From the above table, it may be seen that different degrees of resistance and susceptibility to the infection of the powdery mildew exist in the different varieties of *Triticum vulgare* growing in the field.

Experiment 2

The experiment was made to determine the specialization of the conidia. Conidia of *Erysiphe graminis* parasitic on *Triticum Spelta* were inoculated on the leaves of host plants belonging to the genera Hordeum, Triticum, Secale, Avena and Poa. The method used was to make a spore-suspension of the conidia, and spray them on the host plants in the green house by means of an atomizer.

TABLE 14

Results of the inoculation experiments on Hordeum, Triticum, Secale, Avena, and Poa with the conidia of *Erysiphe graminis* parasitic on *Triticum Spelta*.

Exp. No.	Host plants	Date of sowing	Date of inoculation	Date of infection	Date of appearance of perithecia
1	Avena sativa (Belgium No. 12)	1926 XI. 3	1926 XII. 16	1926 0	1927 0
2	Hordeum sativum var. hexastichon (Marumi No. 15)	,,	,,	0	0
3	Hordeum sativum var. distichon	,,	,,	0	0
4	Avena sativa (Victoria No. 1)	,,	,,	0	0
5	Hordeum sativum var. vulgare (Mitsukigo No. 1)	,,	,,	0	0
6	Hordeum sativum var. vulgare (Sapporo rokkaku)	,,	,,	0	0
7	Secale cereale	,,	,,	0	0
8	Triticum Spelta	,,	,,	XII. 19	I. 16
9	Triticum compactum	,,	,,	XII. 18	I. 14
10	Triticum vulgare (Turkey Red)	,,	,,	,,	,,
11	Triticum dicoccum (Emmer)	,,	,,	0	0
12	Triticum monococcum	,,	,,	XII. 18	0
13	Triticum turgidum	,,	,,	XII. 19	I. 18
14	Triticum durum (Belotourka)	,,	,,	XII. 18	0
15	Poa pratensis	1932	1932 XI. 3	1932 0	1932 0

The writer made observations every day for two months after the sowing of the seeds. The susceptible species belonged to the single genus Triticum. The conidia, which were used in this experi-

ment, evidently belonged to the race of *Erysiphe graminis* f. sp. *Tritici*. Conidia formed on *Triticum spelta* were employed in all the following experiments.

In the present experiment, *Triticum dicoccum* var. *Emmer* proved to be the only one immune variety among the wheat. In *T. monococcum* and *T. durum* (Belotourka), the infection spots gradually disappeared after the maturity of the host leaves.

Experiment 3

Wheat seeds, obtained from the Hokkaido Agricultural Experiment Station, were sown in pots in a green house, and the inoculation experiments were made using the same method as in experiment 2.

TABLE 15

Results of the inoculation experiments with conidia of *Erysiphe graminis* parasitic on *Triticum Spelta* on the varieties of wheat obtained from the Hokkaido Agricultural Experiment

Exp. No.	Varieties of Wheat	Date of inoculation	Date of infection	Degree of infection	
		1927		VI. 8	VII. 5
1	Triticum vulgare (Kota 6404)	V. 28	VI. 1	4	4
2	T. vulgare (Sapporo No. 9)	VI. 5	VI. 7	1	3
3	T. vulgare (Marquis 4051)	,,	,,	1	2
4	T. Spelta (638)	V. 28	VI. 1	2	4
5	T. compactum (5036)	,,	V. 31	3	4
6	T. turgidum (Alaska 3914)	,,	VI. 1	3	2
7	T. Algerian (Macaroni 3862)	,,	,,	2	1
8	T. durum (Belotourka 3972)	,,	V. 31	4	0
9	T. polonicum (1349)	,,	,,	3	0
10	T. monococcum (5725)	VI. 5	VI. 7	1	0
11	T. dicoccum (Emmer 3933)	,,	0		
12	T. dicoccum (Khapli 6400)	,,	0		

The seeds were sown on May 14, 1927.

In No's. 2, 3, 10, 11 and 12, the mycelial spot did not appear in the first inoculation. On June 5, they were again inoculated. Among them, in No's. 2, 3 and 10, the white mycelial patches were produced on June 7.

According to the observations on June 8, and July 5, *Triticum vulgare* (Kota 6404, Sapporo No. 9, and Marquis 4051), *T. Spelta* (638), *T. compactum* (5036), and *T. Algerian* (Macaroni 3862) proved to belong to the susceptible varieties, and *T. durum* (Belotourka 3972), *T. polonicum* (1349), and *T. monococcum* (5725) belonged to the resistant. After two months, in the former group, the leaves and stems turned yellow in color, while in the latter, they continued to show the normal heathy growth. *T. dicoccum* (Emmer 3933, and Khapli 6400) proved to be immune.

Experiment 4

Seventy-six varieties of wheat cultivated in this country were tested to determine the degree of their susceptiblity to *Erysiphe graminis* f. sp. *Tritici*.

The wheat seeds used in the experiments whose results are tabulated in tables 16 and 17 were distributed from the Hokkaido Agricultural Experiment Station.

In tables 18 and 19, are reported the results of the inoculation experiments using plants grown from seeds received from the Experiment Station of the Department of Agriculture and Forestry at Konosu.

In the experiments reported in table 20, the plants grown from seeds received from France and Italy were used.

Each variety was sown in five pots, and the inoculation experiments were made out of doors.

TABLE 16

Results of the inoculation experiments with the conidia of *Erysiphe graminis* f. sp. *Tritici* on the varieties of wheat obtained from the Hokkaido Agricultural Experiment Station.

Exp. No.	Varieties of wheat	Date of sowing	Date of inocu-lation	Date of infection	Degree of in-fection
	Spring wheat	1931	1931	1931	1931
1	Triticum vulgare var. graecum KÖRN. (Hokudai No. 2)	VI. 22	VII. 16	VIII. 2	VIII. 4 1
2	,,	,,	VII. 23	VII. 31	1
3	,,	,,	,,	,,	1
4	,,	,,	,,	VII. 27	1
5	,,	,,	,,	VII. 25	1
6	T. vulgare var. erythrospermum KORN. (Sapporo harukomugi No. 9)	,,	VII. 16	VII. 23	VII. 27 1
7	,,	,,	,,	VII. 22	1
8	,,	,,	,,	VII. 23	1
9	,,	,,	,,	,,	1
10	,,	,,	,,	,,	1
11	T. vulgare var. ferrugineum KÖRN. (Wase komugi 3830)	,,	,,	VII. 20	4
12	,,	,,	,,	,,	4
13	,,	,,	,,	,,	4
14	,,	,,	,,	,,	4
15	,,	,,	,,	,,	4
16	T. vulgare var. lutescens KÖRN. (Ekishirazu)	,,	,,	,,	4
17	,,	,,	,,	,,	4
18	,,	,,	,,	,,	4
19	,,	,,	,,	,,	4
20	,,	,,	,,	,,	4
21	T. vulgare var. velutinum KÖRN. (Minnesota No. 166)	,,	,,	,,	3
22	,,	,,	,,	,,	3
23	,,	,,	,,	,,	3
24	,,	,,	,,	,,	3
25	,,	,,	,,	,,	3

TABLE 16. (*Continued*)

Exp. No.	Varieties of wheat	Date of sowing	Date of inocu-lation	Date of infection	Degree of in-fection
26	T. vulgare var. graecum KÖRN. (Early Baat)	VI. 22	VII. 16	VII. 20	VII. 27 3
27	,,	,,	,,	,,	3
28	,,	,,	,,	VII. 21	3
29	,,	,,	,,	VII. 20	3
30	,,	,,	,,	,,	3
31	T. vulgare var. milturum KÖRN. (Iga-chikugo X Oregon)	,,	,,	,,	4
32	,,	,,	,,	,,	4
33	,,	,,	,,	,,	4
34	,,	,,	,,	,,	4
35	,,	,,	,,	,,	4
36	T. *monococcum* var. *Hornemanni* KORN.	VII. 20	VIII. 3		VIII. 17 0
37	,,	,,	,,		0
38	,,	,,	,,		0
39	,,	,,	,,		0
40	,,	,,	,,		0
41	T. dicoccum var. farrum KÖRN.	,,	,,	VIII. 7	2
42	,,	,,	,,	VIII. 8	2
43	,,	,,	,,	VIII. 7	2
44	,,	,,	,,	,,	2
45	,,	,,	,,	VIII. 8	2
46	T. durum var. hordeiforme KÖRN. (Belotourka)	,,	,,	VIII. 5	4
47	,,	,,	,,	,,	4
48	,,	,,	,,	,,	4
49	,,	,,	,,	VIII. 6	4
50	,,	,,	,,	VIII. 5	4
51	T. durum var. melanopus KÖRN. (Algerian macaroni)	,,	,,	VIII. 6	4
52	,,	,,	,,	,,	3
53	,,	,,	,,	VIII. 5	3
54	,,	,,	,,	,,	3
55	,,	,,	,,	VIII. 7	3

TABLE 16. (*Continued*)

Exp. No.	Varieties of wheat	Date of sowing	Date of inocu-lation	Date of infection	Degree of in-fection
56	T. durum var. hordeiforme KÖRN. (Monad, C. I. No. 3320)	VII. 20	VIII. 3	VIII. 5	VIII. 17 4
57	,,	,,	,,	VIII. 6	4
58	,,	,,	,,	VIII. 7	4
59	,,	,,	,,	VIII. 6	4
60	,,	,,	,,	,,	4
61	T. polonicum var. chrysospermum KÖRN. (de Pologne ou d'Astrakan)	,,	,,	,,	3
62	,,	,,	,,	,,	3
63	,,	,,	,,	VIII. 5	4
64	,,	,,	,,	VIII. 6	3
65	,,	,,	,,	,,	3
66	T. turgidum var. pseudocervinum KÖRN. (Alaska)	,,	VIII. 4	,,	4
67	,,	,,	,,	VIII. 8	4
68	,,	,,	,,	,,	4
69	,,	,,	,,	VIII. 7	4
70	,,	,,	,,	,,	4
	Winter wheat				
71	T. vulgare var. graecum KÖRN. (1101-7-a)	VII. 20	VIII. 4	VIII. 6	4
72	,,	,,	,,	,,	4
73	,,	,,	,,	,,	4
74	,,	,,	,,	,,	4
75	,,	,,	,,	,,	4
76	T. vulgare var. erythrospermum KORN. (Turkey Red)	,,	,,	,,	4
77	,,	,,	,,	,,	4
78	,,	,,	,,	,,	4
79	,,	,,	,,	,,	4
80	,,	,,	,,	,,	4

TABLE 16. (*Continued*)

Exp. No	Varieties of wheat	Date of sowing	Date of inoculation	Date of infection	Degree of infection
81	T. vulgare var. ferrugineum KÖRN. (Akakawa-aka No. 1)	VII. 20	VIII. 4	VIII. 6	VIII. 17 4
82	,,	,,	,,	,,	4
83	,,	,,	,,	,,	4
84	,,	,,	,,	,,	4
85	,,	,,	,,	,,	4
86	T. vulgare var. barbarossa KÖRN. (Bearded Velvet Chaff)	VIII. 5	VIII. 17	VIII. 19	VIII. 31 4
87	,,	,,	,,	,,	4
88	,,	,,	,,	,,	4
89	,,	,,	,,	,,	4
90	,,	,,	,,	,,	4
91	T. vulgare var. albidum KÖRN. (Martin No. 8)	,,	,,	,,	4
92	,,	,,	,,	,,	4
93	,,	,,	,,	,,	4
94	,,	,,	,,	,,	4
95	,,	,,	,,	,,	4
96	T. vulgare var. lutescens KÖRN. (Winter wheat, 4907)	,,	,,	,,	4
97	,,	,,	,,	,,	4
98	,,	,,	,,	,,	4
99	,,	,,	,,	,,	4
100	,,	,,	,,	,,	4
101	T. vulgare var. alborubrum KÖRN. (Dawson No. 1)	,,	,,	,,	4
102	,,	,,	,,	,,	4
103	,,	,,	,,	,,	4
104	,,	,,	,,	,,	4
105	,,	,,	,,	,,	4
106	T. vulgare var. milturum KÖRN. (Akasabi-shirazu No. 1)	,,	,,	,,	4
107	,,	,,	,,	,,	4
108	,,	,,	,,	,,	4
109	,,	,,	,,	,,	4
110	,,	,,	,,	,,	4

TABLE 16. (*Continued*)

Exp. No.	Varieties of wheat	Date of sowing	Date of inoculation	Date of infection	Degree of infection
111	T. compactum var. icterinum KÖRN. (Hokkaido Agr. Exp. Stat. No. 6355)	VIII. 5	VIII. 18	VIII. 20	VIII. 31 4
112	,,	,,	,,	,,	4
113	,,	,,	,,	,,	4
114	,,	,,	,,	,,	4
115	,,	,,	,,	,,	4
116	T. compactum var. erinaceum KÖRN. (Hokkaido Agr. Exp. Stat. No. 6356)	VIII. 6	,,	,,	4
117	,,	,,	,,	,,	4
118	,,	,,	,,	,,	4
119	,,	,,	,,	,,	4
120	,,	,,	,,	,,	4
121	T. compactum var. Wernerianum KÖRN. (Hokkaido Agr. Exp. Stat. No. 6354)	,,	,,	,,	4
122	,,	,,	,,	,,	4
123	,,	,,	,,	,,	4
124	,,	,,	,,	,,	4
125	,,	,,	,,	,,	4
126	T. compactum var. Wittmackianum KÖRN. (B. 28, 3. 1. 1. 1.)	,,	,,	VIII. 21	4
127	,,	,,	,,	,,	4
128	,,	,,	,,	,,	4
129	,,	,,	,,	,,	4
130	,,	,,	,,	,,	4
131	T. compactum var. creticum KÖRN. (Hokkaido Agr. Exp. Stat. No. 6357)	,,	,,	,,	4
132	,,	,,	,,	,,	4
133	,,	,,	,,	,,	4
134	,,	,,	,,	,,	4
135	,,	,,	,,	,,	withered
136	T. Spelta var. Dukamelianum KÖRN. (J. 4. 4. 1. 1. 1.)	,,	,,	,,	4
137	,,	,,	,,	,,	4
138	,,	,,	,,	,,	4
139	,,	,,	,,	,,	4
140	,,	,,	,,	,,	4

As shown in table 16, among the varieties of *Triticum vulgare*, Hokudai No. 2 and Sapporo Harukomugi No. 9 belong to the resistant varieties. *T. monococcum* var. *Hornemanni* was not infected although the inoculation experiments had been repeated on Aug. 3 and Aug. 17. *T. dicoccum* var. *farrum* proved to be resistant, although after two days from the inoculation, the haustoria were produced in the epidermal cells. In tables 14 and 15, *T. monococcum* was included in the resistant varieties, and two varieties of *T. dicoccum* proved to be immune. Therefore the next experiment was carried out.

TABLE 17

Results of inoculation experiments on *T. monococcum* and *T. dicoccum*.

Exp. No.	Varieties of wheat	Date of sowing	Date of inoculation	Date of infection	Degree of infection
1	T. monococcum var. vulgare	1931 X. 19	XI. 10	XI. 25	XII. 4 1
2	,,	,,	,,	XI. 16	1
3	,,	,,	,,	XI. 14	1
4	,,	,,	,,	,,	1
5	,,	,,	,,	withered	
6	T, dicoccum var. farrum	,,	,,	XI. 14	2
7	,,	,,	,,	XI. 12	2
8	,,	,,	,,	,,	2
9	,,	,,	,,	,,	3
10	,,	,,	,,	,,	2
11	T. monococcum var. Hornemanni	,,	Not germinated		
12	,,	,,	,,		
13	,,	,,	,,		
14	,,	,,	,,		
15	,,	,,	,,		

In the results of the above experiment, *Triticum monococcum* var. *vulgare* and *T. dicoccum* var. *farrum* proved to be resistant. In *T. dicoccum*, both resistant and immune strains were distinctly recognized. It was a disappointment that *T. monococcum* var. *Hornemanni* seeds did not germinate in this experiment.

TABLE 18

Results of the inoculation experiments with the conidia of *Erysiphe graminis* f. sp. *Tritici* on varieties of wheat of foreign origin received from the Experiment Station of the Department of Agriculture and Forestry at Konosu.

Exp. No.	Varieties of wheat	Date of sowing	Date of inocu-lation	Date of infection	Degree of in-fection
		1931			VIII. 31
141	Tetsurei zairaishu	VIII. 6	VIII. 18	VIII. 20	2
142	,,	,,	,,	,,	2
143	,,	,,	,,	,,	3
144	,,	,,	,,	,,	3
145	,,	,,	,,	,,	2
146	Extra Kolben	,,	,,	,,	1
147	,,	,,	,,	,,	1
148	,,	,,	,,	,,	1
149	,,	,,	,,	withered	
150	,,	,,	,,	VIII. 22	1
151	Ritter	,,	,,	VIII. 20	4
152	,,	,,	,,	,,	4
153	,,	,,	,,	,,	4
154	,,	,,	,,	,,	4
155	,,	,,	,,	,,	4
					IX. 19
156	Garnet Ot. 652	VIII. 21	IX. 3	IX. 9	4
157	,,	,,	,,	,,	4
158	,,	,,	,,	IX. 8	4
159	,,	,,	,,	IX. 5	4
160	,,	,,	,,	IX. 7	4
161	Huron Ot. 3	,,	,,	IX. 9	4
162	,,	,,	,,	IX. 8	4
163	,,	,,	,,	IX. 9	4
164	,,	,,	,,	,,	4
165	,,	,,	,,	,,	4

TABLE 18. *(Continued)*

Exp. No.	Varieties of wheat	Date of sowing	Date of inoculation	Date of infection	Degree of infection
					IX. 19
166	Harvest Queen	VIII. 21	IX. 3	IX. 8	4
167	,,	,,	,,	,,	4
168	,,	,,	,,	,,	4
169	,,	,,	,,	,,	4
170	,,	,,	,,	,,	4
171	Hard Federation	,,	,,	,,	4
172	,,	,,	,,	,,	4
173	,,	,,	,,	,,	4
174	,,	,,	,,	,,	4
175	,,	,,	,,	,,	4
176	Bunyip	,,	,,	,,	4
177	,,	,,	,,	,,	4
178	,,	,,	,,	,,	4
179	,,	,,	,,	,,	4
180	,,	,,	,,	,,	4
					IX. 25
181	White Odessa	VIII. 29	IX. 10	IX. 12	4
182	,,	,,	,,	,,	4
183	,,	,,	,,	,,	4
184	,,	,,	,,	IX. 14	4
185	,,	,,	,,	,,	4
186	Martin	,,	,,	,,	4
187	,,	,,	,,	,,	4
188	,,	,,	,,	,,	4
189	,,	,,	,,	,,	4
190	,,	,,	,,	IX. 12	4
191	Russian No. 25	,,	,,	,,	4
192	,,	,,	,,	,,	4
193	,,	,,	,,	,,	4
194	,,	,,	,,	,,	4
195	,,	,,	,,	,,	4

TABLE 18. (*Continued*)

Exp. No.	Varieties of wheat	Date of sowing	Date of inocu-lation	Date of infection	Degree of in-fection
196	Podolanka	VIII. 29	IX. 10	IX. 14	IX. 25 4
197	,,	,,	,,	IX. 12	4
198	,,	,,	,,	IX. 14	3
199	,,	,,	,,	IX. 12	4
200	,,	,,	,,	,,	4
201	? Lwowianka	,,	,,	IX. 14	4
202	,,	,,	,,	IX. 12	4
203	,,	,,	,,	,,	4
204	,,	,,	,,	IX. 14	4
205	,,	,,	,,	IX. 12	4
206	Gentile Rosso fam. 58	IX. 2	IX. 15	IX. 17	IX. 30 4
207	,,	,,	,,	,,	4
208	,,	,,	,,	,,	4
209	,,	,,	,,	,,	4
210	,,	,,	,,	,,	4
211	Altai 86	,,	,,	,,	4
212	,,	,,	,,	,,	4
213	,,	,,	,,	,,	4
214	,,	,,	,,	,,	4
215	,,	,,	,,	,,	4
216	Altai 414	,,	,,	,,	4
217	,,	,,	,,	,,	4
218	,,	,,	,,	,,	4
219	,,	,,	,,	,,	4
220	,,	,,	,,	,,	4
221	Russian No. 38	,,	,,		X. 5 0
222	,,	,,	(IX. 21)		0
223	,,	,,	,,		0
224	,,	,,	,,		0
225	,,	,,	,,		0

TABLE 18. (*Continued*)

Exp. No.	Varieties of wheat	Date of sowing	Date of inocu-lation	Date of infection	Degree of in-fection
					IX. 30
226	Russian No. 61	IX. 2	IX. 16	IX. 17	2
227	,,	,,	,,	,,	2
228	,,	,,	,,	,,	2
229	,,	,,	,,	,,	3
230	,,	,,	,,	,,	2

Extra Kolben and *Russian No. 61* were the resistant varieties and *Russian* No. 38 proved to be immune. The last mentioned variety was not infected in spite of the twice performed inoculations on Sept. 15 and 21.

TABLE 19

Results of the inoculation experiments with the conidia of *Erysiphe graminis* f. sp. *Tritici* on common wheat, which are cultivated in this country and received from the Experiment Station of the Department of Agriculture and Forestry at Konosu.

Exp. No.	Varieties of wheat	Date of sowing	Date of inocu-lation	Date of infection	Degree of in-fection
		1931			IX. 30
231	Iwate-soshu No. 1 (Iwate)	IX. 2	IX. 15	IX. 17	4
232	,,	,,	,,	,,	4
233	,,	,,	,,	,,	4
234	,,	,,	,,	,,	4
235	,,	,,	,,	,,	4
					X. 5
236	Daruma No. 2 (Miyagi)	IX. 3	IX. 17	IX. 22	4
237	,,	,,	,,	,,	4
238	,,	,,	,,	,,	4
239	,,	,,	,,	,,	4
240	,,	,,	,,	,,	4

TABLE 19. (*Continued*)

Exp. No.	Varieties of wheat	Date of sowing	Date of inocu-lation	Date of infection	Degree of in-fection
241	Akita-zairaishu (Akita)	IX. 3	IX. 17	IX. 19	X. 5 4
242	,,	,,	,,	IX. 22	4
243	,,	,,	,,	,,	3
244	,,	,,	,,	,,	3
245	,,	,,	,,	,,	4
246	Waraide (Yamagata)	,,	,,	,,	4
247	,,	,,	,,	,,	4
248	,,	,,	,,	,,	4
249	,,	,,	,,	,,	4
250	,,	,,	,,	,,	4
251	Sunagawa-daruma (Fukushima)	IX. 9	IX. 23	IX. 28	X. 15 4
252	,,	,,	,,	IX. 29	4
253	,,	,,	,,	,,	4
254	,,	,,	,,	,,	4
255	,,	,,	,,	IX. 28	4
256	Shirasaya No. 2 (Ibaragi)	,,	,,	,,	4
257	,,	,,	,,	IX. 29	4
258	,,	,,	,,	,,	4
259	,,	,,	,,	,,	4
260	,,	,,	,,	IX. 28	4
261	Akaboro No. 1 (Tochigi)	,,	,,	IX. 26	4
262	,,	,,	,,	IX. 28	4
263	,,	,,	,,	IX. 26	4
264	,,	,,	,,	,,	4
265	,,	,,	,,	IX. 28	4
266	Nitta-wase (Gumma)	IX. 10	,,	IX. 29	X. 16 4
267	,,	,,	,,	,,	4
268	,,	,,	,,	IX. 28	4
269	,,	,,	,,	IX. 26	4
270	,,	,,	,,	IX. 29	4

TABLE 19. (*Continued*)

Exp. No.	Varieties of wheat	Date of sowing	Date of inoculation	Date of infection	Degree of infection
					X. 16
271	Aka-daruma-saki No. 1 (Saitama)	IX. 10	IX. 23	IX. 29	4
272	,,	,,	,,	IX. 28	4
273	,,	,,	,,	IX. 29	4
274	,,	,,	,,	,,	4
275	,,	,,	,,	IX. 28	4
					X. 20
276	Saikan (Chiba)	IX. 18	X. 5	X. 8	4
277	,,	,,	,,	,,	4
278	,,	,,	,,	,,	4
279	,,	,,	,,	,,	4
280	,,	,,	,,	,,	4
281	Soshu (Tokyo)	,,	,,	,,	4
282	,,	,,	,,	,,	4
283	,,	,,	,,	X. 7	4
284	,,	,,	,,	X. 9	4
285	,,	,,	,,	X. 7	4
286	Ojima-wase (Tokyo)	,,	,,	X. 9	4
287	,,	,,	,,	,,	4
288	,,	,,	,,	X. 8	4
289	,,	,,	,,	,,	4
290	,,	,,	,,	,,	4
291	Shiro-bozu (Kanagawa)	,,	,,	X. 9	4
292	,,	,,	,,	,,	4
293	,,	,,	,,	X. 8	4
294	,,	,,	,,	X. 9	4
295	,,	,,	,,	,,	4
					X. 26
296	Akakomugi (Toyama)	IX. 25	X. 7	X. 10	3
297	,,	,,	,,	X. 11	3
298	,,	,,	,,	X. 12	3
299	,,	,,	,,	X. 11	3
300	,,	,,	,,	X. 12	3

TABLE 19. (*Continued*)

Exp. No.	Varieties of wheat	Date of sowing	Date of inocu-lation	Date of infection	Degree of in-fection
					X. 26
301	Nishimura (Fukui)	IX. 25	X. 7	X. 10	4
302	,,	,,	,,	,,	4
303	,,	,,	,,	,,	4
304	,,	,,	,,	,,	4
305	,,	,,	,,	,,	4
306	Akage-gumbai (Yamanashi)	,,	,,	,,	4
307	,,	,,	,,	,,	4
308	,,	,,	,,	,,	4
309	,,	,,	,,	X. 9	4
310	,,	,,	,,	X. 10	4
311	Shibu-shirazu (Nagano)	,,	,,	,,	4
312	,,	,,	,,	,,	4
313	,,	,,	,,	,,	4
314	,,	,,	,,	X. 11	4
315	,,	,,	,,	X. 10	4
316	Aichi-akatake No. 1 (Aichi)	,,	,,	X. 12	4
317	,,	,,	,,	X. 11	4
318	,,	,,	,,	X. 10	4
319	,,	,,	,,	,,	4
320	,,	,,	,,	,,	4
321	Mihara (Hyogo)	,,	,,	X. 12	4
322	,,	,,	,,	X. 10	4
323	,,	,,	,,	X. 9	4
324	,,	,,	,,	X. 10	4
325	,,	,,	,,	,,	4
					X. 27
326	Shin-nakanaga (Hyogo)	IX. 29	X. 9	X. 17	4
327	,,	,,	,,	X. 16	4
328	,,	,,	,,	,,	4
329	,,	,,	,,	X. 17	4
330	,,	,,	,,	X. 14	4

TABLE 19. *(Continued)*

Exp. No.	Varieties of wheat	Date of sowing	Date of inocu-lation	Date of infection	Degree of in-fection
					X. 27
331	Ejima No. 1 (Shimane)	IX. 29	X. 9	X. 17	4
332	,,	,,	,,	,,	4
333	,,	,,	,,	X. 14	4
334	,,	,,	,,	X. 16	4
335	,,	,,	,,	,,	4
336	Hatada-komugi No. 2 (Okayama)	,,	,,	,,	4
337	,,	,,	,,	,,	4
338	,,	,,	,,	X. 15	4
339	,,	,,	,,	X. 16	4
340	,,	,,	,,	,,	4
341	Wase-chinko (Hiroshima)	,,	X. 10	,,	4
342	,,	,,	,,	X. 13	4
343	,,	,,	,,	,,	4
344	,,	,,	,,	,,	4
345	,,	,,	,,	X. 14	4
346	Wase-komugi (Kagawa)	,,	,,	X. 15	4
347	,,	,,	,,	X. 18	4
348	,,	,,	,,	X. 16	4
349	,,	,,	,,	,,	4
350	,,	,,	,,	X. 17	4
351	Homan (Kochi)	,,	,,	,,	4
352	,,	,,	,,	X. 19	4
353	,,	,,	,,	X. 17	4
354	,,	,,	,,	,,	4
355	,,	,,	,,	X. 18	4
					X. 31
356	Ejima-shinriki (Fukuoka)	X. 5	X. 19	X. 21	4
357	,,	,,	,,	,,	4
358	,,	,,	,,	,,	4
359	,,	,,	,,	,,	4
360	,,	,,	,,	,,	4

TABLE 19. (*Continued*)

Exp. No.	Varieties of wheat	Date of sowing	Date of inocu-lation	Date of infection	Degree of in-fection
					X. 31
361	Haya-komugi (Fukuoka)	X. 5	X. 19	X. 21	4
362	,,	,,	,,	,,	4
363	,,	,,	,,	,,	4
364	,,	,,	,,	,,	4
365	,,	,,	,,	,,	4
366	Shiro-komugi No. 1 (Saga)	,,	,,	,,	4
367	,,	,,	,,	,,	4
368	,,	,,	,,	,,	4
369	,,	,,	,,	,,	4
370	,,	,,	,,	,,	4
371	Shiro-bumpu (Kumamoto)	,,	,,	,,	3
372	,,	,,	,,	,,	3
373	,,	,,	,,	,,	3
374	,,	,,	,,	,,	3
375	,,	,,	,,	,,	3
376	Sanshukotake (Kagoshima)	,,	,,	,,	4
377	,,	,,	,,	,,	4
378	,,	,,	,,	,,	4
379	,,	,,	,,	,,	4
380	,,	,,	,,	,,	4

(The words in brackets are the names of the prefectures).

Almost all varieties tabulated above proved highly susceptible to wheat mildew. Aka-komugi and Shiro-bumpu proved to be less susceptible than the others.

TABLE 20

Results of inoculation experiments with the conidia of *Erysiphe graminis* f. sp. *Tritici* on the species of Triticum which were sent from the Agricultural Experiment Stations in France and Italy.

Exp. No.	Species of wheat	Date of sowing	Date of inocu-lation	Date of infection	Degree of in-fection
381	Triticum Tumonia (France)	1931 X. 19	XI. 7	XI. 9	XII. 4 4
382	,,	,,	,,	XI. 10	4
383	,,	,,	,,	,,	4
384	,,	,,	,,	XI. 9	4
385	,,	,,	,,	,,	4
386	T. Tumonia (Italy)	,,	,,	XI. 10	4
387	,,	,,	,,	XI. 11	4
388	,,	,,	,,	XI. 10	4
389	,,	,,	,,	,,	4
390	,,	,,	,,	,,	4
391	T. abyssinicum (France)	,,	,,	XI. 11	3
392	,,	,,	,,	XI. 9	3
393	,,	,,	,,	,,	3
394	,,	,,	,,	XI. 10	3
395	,,	,,	,,	,,	3
396	T. boatum (Pays-Bas)	,,	XI. 11	0	
397	,,	,,	(XI. 23)	0	
398	,,	,,	,,	0	
399	,,	,,	,,	0	
400	,,	,,	,,	0	
401	T. Thaouder (Italy)	,,	XI. 7	XI. 11	XII. 4 3
402	,,	,,	,,	,,	3
403	,,	,,	,,	,,	3
404	,,	,,	,,	,,	3
405	,,	,,	,,	,,	3

The seeds of the above varieties were received from the Agı cultural Experiment Stations in France and Italy. *Triticum boatu* proved to be immune, but this species is not numbered among t common wheats.

Summary of the inoculation experiments on eighty-one varieties of wheat.

The results of the inoculation experiments with conidia produced on *Triticum Spelta* are as follows:

In *Triticum vulgare*, both susceptible and resistant varieties are included. Among the varieties of *T. vulgare* tested in these experiments, the most highly resistant and perfectly immune varieties could not be found.

In *T. turgidum*, *T. Spelta*, and *T. compactum*, the susceptible character was retained throughout all vegetative stages from the seedling to the ripening stage.

The seedlings of *T. polonicum*, and *T. durum* were highly susceptible, but in the ripening stage, they became highly resistant. Sometimes they are mistaken to be immune in the field observation.

T. monococcum and *T. dicoccum* proved to be resistant throughout all the stages, but *T. monococcum* var. *Hornemanni* still remains undetermined on account of the non-germination of its seed.

Russian No. 38, and *T. boatum* belonged to the immune varieties.

Experiment 5

As a result of further inoculation experiments, *Triticum dicoccum, Khapli 6400, Emmer 3933,* and *Russian No. 38* proved to be immune varieties. *T. monococcum* var. *Hornemanni* still remained undetermined. The following experiments were repeated for the ascertainment of these facts.

TABLE 21

Results of inoculation experiments on *Triticum dicoccum* with the conidia of *Erysiphe graminis* parasitic on *Triticum vulgare.*

Varieties of wheat	Date of sowing	Date of inoculation	Date of infection
T. dicoccum, Emmer 3933	VIII. 11	VIII. 24	0
T. dicoccum, Khapli 6400	,,	,,	0

In this experiment, the conidia on *Triticum vulgare* were used for inoculation.

TABLE 22

Showing the results of the inoculation experiments on *Triticum dicoccum* using the conidia of *Erysiphe graminis* parasitic on *Triticum Spelta*.

Varieties of wheat		Date of sowing	Date of inoculation	Date of infection	Treatment of the host plants
T. dicoccum, Emmer	a	XI. 17	II. 23	0	On stripped epidermis
	b	,,	,,	0	On epidermis wounded with needle
T. dicoccum, Khapli	a	I. 18	,,	0	On stripped epidermis
	b	,,	,,	0	On epidermis wounded with needle

In this experiment, the conidia formed on *T. Spelta* were inoculated on *T. dicoccum, Khapli* and *Emmer*. They were not infected even though the epidermis of the leaves had been stripped off with a razor or wounded with a needle.

TABLE 23

Results of inoculation experiments on *Triticum dicoccum* and *T. monococcum* using conidia of *Erysiphe graminis* parasitic on *Triticum dicoccum* var. *farrum*.

Varieties of wheat	Date of sowing	Date of inoculation	Date of infection	Degree of infection
T. dicoccum, Khapli	XII. 8	I. 18	0	
	,,	withered	0	
T. dicoccum, Emmer	XII. 17	I. 18	0	
	,,	,,	0	
T. monococcum var. *Hornemanni*	I. 9	II. 9	II. 15	(II. 23) 2
	,,	Not germinated		
Russian No. 38	II. 16	II. 26	0	
	,,	,,	0	

In this experiment, conidia from the fungus on *T. dicoccum* var. *farrum* were used for inoculation. After the inoculation, the pots were placed in the green house side by side with the pots of af-

fected *T. dicoccum* var. *farrum* and left to natural infection. In this experiment, *T. monococcum* var. *Hornemanni* only was infected. The inoculation experiments were repeated thrice on *T. monococcum* var. *Hornemanni.*

TABLE 24

Results of the inoculation experiments on *Triticum monococcum* and *T. dicoccum* with the conidia of *Erysiphe graminis* parasitic on *Triticum vulgare.*

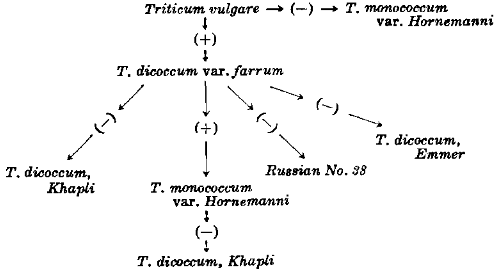
Varieties of wheat	Date of sowing	Date of inoculation	Date of infection	Degree of infection
T. monococcum var. Hornemanni	II. 16	II. 29	0	
T. dicoccum var. farrum	II. 22	,,	III. 5	(III. 16) 2

In this experiment, the conidia on *T. vulgare* (Ekishirazu) were used for inoculation. In this case, *T. monococcum* var. *Hornemanni* was not infected.

From the results of experiments 4 and 5 the relation of the conidia to the degree of infection on different varieties of *T. monococcum* and *T. dicoccum* is shown in the following table.

TABLE 25

Relation of the conidia to the degree of infection on *Triticum monococcum* and *T. dicoccum.*



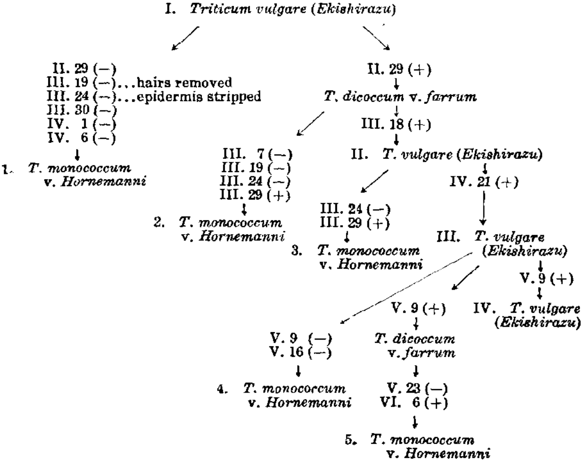
Triticum monococcum var. *Hornemanni* was not infected with the conidia formed on *T. vulgare*, but it was infected by the conidia formed on *T. dicoccum* var. *farrum*. Therefore, the next experiment was made.

Experiment 6

The present experiment was carried out by the procedure presented in the following diagram.

TABLE 26

Results of the inoculation experiments with the conidia of *Erysiphe graminis* parasitic on *Triticum vulgare* on *Triticum monococcum*, *T. dicoccum* and *T. vulgare*.



In this experiment, the affected stock wheat (*T. vulgare*, Ekishirazu) which served as the source of the conidia was always placed in an isolated room in the green house in order to prevent natural infection. The spore-masses were inoculated with a needle on certain parts of the leaves and sheaths of the wheat to be experimented upon, then the plants thus inoculated were covered for 24 hours with bell-jars.

T. vulgare (I) was a highly susceptible variety and the infection spots appeared in maximum quantity (4). The conidia produced on *T. vulgare* were inoculated on *T. monococcum* var. *Hornemanni* and on *T. dicoccum* var. *farrum*. In the former, the infection spots did not appear in spite of the repetition of the inoculation six times, even when in the second inoculation, the epidermal hairs of the leaves had been removed, and in the third inoculation, the epidermis had been stripped off with a razor. In *T. dicoccum* var. *farrum*, the infection spots appeared in intermediate quantity (2). The conidia formed on this host were inoculated on *T. monococcum* var. *Hornemanni* and on *T. vulgare* (II). In this case, both varieties were infected, and the degree of infection of the powdery mildew on *T. vulgare* (II) appeared to be intermediate (2). On *T. monococcum* var. *Hornemanni*, the infection spots appeared once in four times in minimum quantity (1). The conidia formed on *T. vulgare* (II) were inoculated on *T. monococcum* var. *Hornemanni* and *T. vulgare* (III). Both varieties were infected, and it was the maximum degree of infection which appeared on *T. vulgare* (III). Thus, the degree of infection on *T. vulgare* (III) returned to that on *T. vulgare* (I). The conidia on *T. vulgare* (III) were inoculated on *T. monococcum* var. *Hornemanni*, on *T. dicoccum* var. *farrum* and on *T. vulgare* (IV). *T. monococcum* var. *Hornemanni* was not infected. The other two varieties were infected. The maximum degree (4) of infection appeared on *T. vulgare* (IV). The conidia formed on *T. dicoccum* var. *farrum* caused the infection again on *T. monococcum* var. *Hornemanni*.

In the present experiments, conidia from the parasite on *T. vulgare* (I) and (III) did not infect *T. monococcum* var. *Hornemanni*. The last named variety was however infected by the conidia from the

parasite on either *T. dicoccum* var. *farrum* or on *T. vulgare* (II), which had passed through *T. dicoccum* var. *farrum*. It was found that in order for the conidia on *T. vulgare* (Ekishirazu) to cause infection on *T. monococcum* var. *Hornemanni*, the fungus must pass *T. dicoccum* var. *farrum* as a host.

Experiment 7

In this experiment, the morphological characters of the conidia of *Erysiphe graminis* f. sp. *Tritici* used in experiment 6 were studied. The matured conidia were used for measurements.

TABLE 27

Measurements of the conidia produced on *T. vulgare* (I).

Length in Micron.

Class	31.2	32.4	33.6	34.8	36.0	37.2	38.4	39.6	40.8
Frequency	2	8	10	16	30	17	9	4	4

Width in Micron.

Class	13.2	14.4	15.6	16.8	18.0
Frequency	3	31	52	9	5

TABLE 28

Measurements of the conidia produced on *T. vulgare* (IV).

Length in Micron.

Class	28.8	30.0	31.2	32.4	33.6	34.8	36.0	37.2	38.4	39.6	40.8
Frequency	3	7	12	13	15	16	19	7	6	1	1

TABLE 28. (*Continued*)

Width in Micron.

Class	13.2	14.4	15.6	16.8	18.0	19.2	20.4
Frequency	2	26	43	22	5	1	1

TABLE 29

Measurements of the conidia produced on
T. dicoccum var. *farrum*.

Length in Micron.

Class	28.8	30.0	31.2	32.4	33.6	34.8	36.0	37.2	38.4	39.6
Frequency	1	3	10	14	28	13	12	10	8	1

Width in Micron.

Class	12.0	13.2	14.4	15.6	16.8	18.0
Frequency	1	7	28	41	18	5

From the above tables, one may learn that in the width of the conidia, they were almost the same in three cases, but in the length, a remarkable difference may be recognized. In the forms on *Triticum vulgare* (I) and (IV), the class of highest frequency was 36.0 μ. But in the latter, the conidia which are less than 36.0 μ in length, were more numerous than in *T. vulgare* (I). The form of conidia on *T. dicoccum* var. *farrum* was conspicuously smaller than of those on *T. vulgare*. When the conidia formed on *T. vulgare* had been transferred onto *T. dicoccum* var. *farrum*, the length of the conidia became conspicuously shorter, but when they had been retransferred

onto *T. vulgare*, the forms of the conidia gradually returned to their original size.

On May 19, 1932, germination experiments with the conidia formed on *T. vulgare* (IV) and *T. dicoccum* var. *farrum* (II) were made in the hanging-drop cultures. As shown in figure 7, the germ tubes of the conidia on *T. dicoccum* var. *farrum* were shorter and larger than those on *T. vulgare;* in addition irregular branches were frequently formed at their apices.

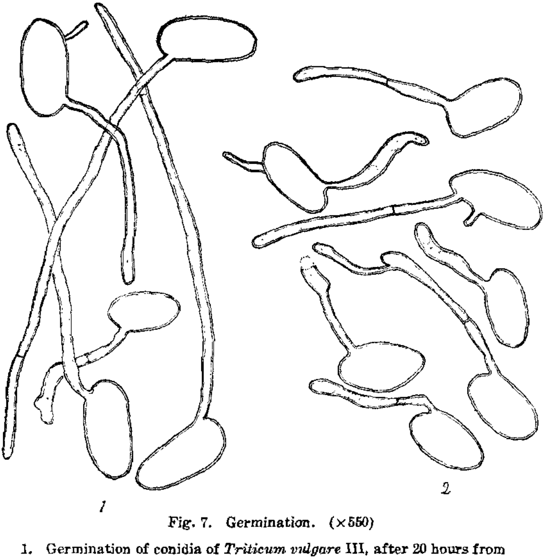


Fig. 7. Germination. (×550)

1. Germination of conidia of *Triticum vulgare* III, after 20 hours from the start of hanging-drop culture.
2. Germination of conidia of *T. dicoccum* var. *farrum*, after 20 hours from the start of hanging-drop culture.

Also, conidia formed on *T. vulgare* and *T. dicoccum* var. *farru* were sown on the leaves of *T. dicoccum* var. *Khapli* which we

placed on moistened filter paper in a Petri-dish. After 24 hours, the epidermis was stripped, and examined. Almost all conidia produced germ-tubes, and their length and size as well as their mode of branching were similar to those found in the former experiment.

Summary of experiments 5, 6 and 7

In 1904, E. S. SALMON (34) recognized the presence of a bridging form in *Erysiphe graminis* parasitic on Bromus. In order that the conidia on *Bromus racemosus* may cause infection on *B. commutatus,* they must pass on *B. hordeaceus.* In this case, the form on *B. hordeaceus* is the bridging form and *B. hordeaceus* is the bridging species. SALMON also noted that *Bromus tectorum* seems probably to be a bridging species, affording a means for the passage of the conidia on *B. arduennensis, B. hordeaceus, B. interruptus, B. commutatus* and *B. secalinus* to *B. sterilis.* Since then, no one has studied on this subject with *Erysiphe graminis.* In 1922, E. C. STAKMAN and M. N. LEVINE (42) noted that in the case of the cereal rust, the presence of a bridging species is very questionable. But from the results of the experiments above described the existence of a bridging form in the cereal mildew must be recognized. That is to say, the form on *T. dicoccum* var. *farrum* is the bridging form and *T. dicoccum* var. *farrum* is the bridging species between *T. vulgare* (Ekishirazu) and *T. monococcum* var. *Hornemanni.*

The morphological characters of the conidia on *T. vulgare* and those on *T. dicoccum* var. *farrum* are different; the former are longer than the latter, besides the germ-tubes of the former are more slender and longer than those of the latter.

When the conidia formed on *T. vulgare* (Ekishirazu) has been passed through *T. dicoccum* var. *farrum,* the power to infect *T. vulgare* (Ekishirazu) was weakened at first although this was the case for only a short time.

Experiment 8

In this experiment, tests were made on the influence of the hydrogen-ion concentration of the medium, in which the wheat seedlings were cultivated.

TABLE 30

Results of inoculation on wheat seedlings cultivated in different hydrogen-ion concentrations of the medium.

Host	Water culture media		Date of culture started	Date of inoculation	Number of spots	Height of wheat
T. vulgare (Ekishirazu)	Control Knop-solution (PH. 5.8-6)		IX. 28	IX. 29	X. 8 2	(Average) 17.93 cm.
	I	a	,,	,,	9	20.93
	PH. 3.6	b	,,	,,	1	19.77
	II	a	,,	,,	0	12.00
	PH. 5	b	,,	,,	1	13.53
	III	a	,,	,,	11	21.17
	PH. 6.8	b	,,	,,	5	22.50
	IV	a	,,	,,	12	17.43
	PH. 10	b	,,	,,	2	19.38
T. dicoccum, Khapli	Control Knop-solution (PH. 5.8-6)		IX. 28	IX. 29	0	24.25
	I	a	,,	,,	0	21.07
	PH. 3.6	b	,,	,,	0	19.65
	II	a	,,	,,	0	Withered
	PH. 5	b	,,	,,	0	19.20
	III	a	,,	,,	0	21.72
	PH. 6.8	b	,,	,,	0	25.47
	IV	a	,,	,,	0	22.13
	PH. 10	b	,,	,,	0	16.27

Young seedlings grown to about 4 cm. in length were culture in Knop solution having different PH. values. Normal Knop solutio (PH. 5.8–6.0) was used for the control. Modified Knop solutio of PH. 3.6 was used for series I. The solution of PH. 5 was use for series II. Calcium biphosphoricum was added to the norm Knop solution for preparing the modified solution. Modified Knc solution of PH. 6.8 was used for series III, and for series IV that PH. 10 was used. For the preparation of these solutions ash w mixed with normal Knop solutions. The cultures were started Sept. 28. After 24 hours, the seedlings were inoculated with conid formed on *T. vulgare* (Ekishirazu). *T. dicoccum*, Khapli was n

infected and proved to be immune. The cultural solutions were renewed every two days, and after 2 weeks, the length of the seedlings was measured. In both kinds of wheat, they attained the greatest growth in the solution of PH. 6.8. In *Triticum vulgare,* the seedlings cultured in the medium of PH. 5, showed the least number of infected spots and the poorest growth in length.

2. Difference in characters between the susceptible and immune varieties of wheat

(1) Morphological differences

For investigation on the morphological difference of each variety of wheat in regard to susceptibility and immunity to the powdery mildew, the different characters were observed as shown in the following table.

TABLE 31

Morphological difference of the susceptible and immune wheat.

Varieties of wheat	Color of coleoptile	Color of leaves	Number of hairs in 1 sq. mm.		Degree of infection
			Upper	Under	
T. vulgare (Wase-komugi)	Light green	Light green	10	5	4—4
T. vulgare (Ekishirazu)	Light green	Light green	20	10	4—4
T. compactum (Hokkaido, Agr. Exp. Stat. No. 63)	Greenish brown	Green	10	5	3—4
T. Spelta var. Dukamelianum (J. 4. 4. 1. 1. 1.)	Greenish russet	Green	5	20	2—4
T. turgidum var. pseudocervinum (Alaska)	Light green	Deep green	20	40	3—2
T. durum var. hordeiforme (Belotourka)	Brownish green	Green	5	Trace	4—0
T. polonicum var. chrysospermum (de Pologne ou d'Astrakan)	Light green	Deep green	10	Trace	3—0
T. dicoccum var. farrum	Greenish Hay's russet	Deep green	50	55	2—0
T. monococcum var. vulgare	,,	,,	30	20	1—0
T. monococcum var. Hornemanni	Greenish russet	,,	50	100	2—0
T. dicoccum, Khapli, 6400	,,	Green	5	20	0
T. dicoccum, Emmer, 3933	Greenish Hay's russet	Deep green	15	15	0

The coleoptiles of *Triticum dicoccum*, *T. monococcum*, and *T. Spelta* are greenish russet or greenish Hay's russet in color, those of *T. compactum* and *T. durum* are brownish green, and the rest are light green. At first, the reddish pigment is found diffused in the cell sap of the subepidermal cells. In this stage, the portion containing the pigment has the property of partial immunity. After about 2 weeks from the germination, the pigment is changed to purplish red in color. The diffused pigment assumes globular shapes in a certain limited number of cells. The pigment becomes then insoluble to water. In this stage, the coleoptile loses the resistant character.

The hairs in an area of 1 sq. mm. were counted under microscope using the square micrometer by means of Leitz's Ultropark. The marginal part of the middle portion of the leaf was used for the counting. The basal cell of the hair is always free from the haustorium, besides the hairs check the adherence of water drops on the epidermis. Therefore, the strains having numerous hairs show the tendency of resistance to the powdery mildew. Also the incubation period for the conidial infection is shorter in the case of the strains having fewer hairs than in those having numerous hairs. In *T. vulgare*, *T. compactum*, *T. Spelta*, *T. turgidum*, *T. durum* and *T. polonicum*, only a few hairs are produced. *T. dicoccum* var. *farrum* and *T. monococcum* have numerous hairs. But this character has no relation to their immunity. In *T. dicoccum*, varieties *Khapli* and *Emmer*, the hairs are far less than those of the susceptible form of *T. dicoccum* var. *farrum*.

The structure of the matured leaf blades of wheat was fully described by J. PERCIVAL (26) in 1921. In 1931, HELEN HART (15) published a paper on the relation between the structure of wheat and the rust. According to her, most of the tissues of wheat in the seedling stage are thin-walled chlorenchyma, with numerous intercellular spaces and the epidermis is then a thin, delicate and easily ruptured cellulose-walled membrane. The rust susceptible tissue in the leaf blade occupies the area between the parallel vascular bundles and extends from the lower to the upper epidermis. The girders of sclerenchyma that accompany some of the vascular bundles separate each collenchyma area from its neighboring area. The width of the area varies in different varieties of wheat and in different species of Triticum.

In *Erysiphe graminis*, the mycelial hyphae on the leaf surface send haustoria into the epidermal cells. As a consequence, the characters of the epidermal cells have a close relation to the penetration of the infection tube. The characters of the epidermal cells are determined by the number of vascular bundles and by the environmental factors. The leaf epidermis just above the vascular bundles in both the upper and lower surfaces is composed of thick-walled cells with thick cuticular layer, especially so in the large vascular bundles.

The infected spots of *Erysiphe graminis* on wheat become elongated along the veins. The production of haustoria is limited to the thin-walled epidermal cells. The creeping mycelial hyphae send haustoria into the cells of the valley of the epidermis, and in this part, the cuticular layer does not develop so well. In the sheath, the same characters were recognized as those in the leaf blade. The development of the thick-walled cells of the epidermis with thick cuticular layer is influenced by the temperature, moisture, light, nutrition, etc. When the wheat is grown under unfavorable conditions, the thin-walled epidermal cells become predominant, thus making the plant susceptible to the attack of the powdery mildew.

The seeds of *T. vulgare* (*Wase-komugi*) were sown on moistened cotton in a glass dish, and it was covered with a bell-jar, and placed on the table of the laboratory. When the seedlings had grown to 10 cm. in length, they were inoculated with conidia. On the third day after the inoculation, white patches began to appear on the leaves at the inoculated portions. These patches become elongated along the veins. After a week, the stripped epidermis from the affected leaf was examined. All epidermal cells were thin-walled. In this stage, haustoria were seen even in the epidermal cells on both sides of the vascular bundles. After three weeks, the mycelial hyphae spread over the surface of the leaf. In this stage, under the abnormal condition, the haustoria were sometimes found in the epidermal cells on both sides of the bundles, besides also even in those of the midrib. This fact was also observed in the specimens collected at Sorachi, in the Province of Ishikari, Hokkaido, in 1931, when the wet weather had continued for a long time.

The relative development of the thin-walled and thick-walled epidermal cells is determined by the relative number of vascular bundles in a certain area. In the cross section of the leaf the distance

was measured from a central vessel in a vascular bundle to that of the neighboring bundle.

TABLE 32

Results of the measurements of the distance from a central vessel in a vascular bundle to that of the neighboring bundle in cross-sections of leaves of susceptible and immune wheat.

A. Highly susceptible varieties	*Triticum vulgare* (Ekishirazu)	252–280 μ
	T. Spelta (J. 4. 4. 1. 1. 1.)	238–266 μ
	T. turgidum (Alaska)	224–252 μ
	T. compactum (Hokkaido, Agr. Exp. Stat. No. 63)	210–252 μ
B. Less susceptible varieties	*T. durum* (Belotourka)	210–238 μ
	T. Polonicum (de Pologne ou d'Astrakan)	168–210 μ
	T. dicoccum var. *farrum*	168–238 μ
C. Resistant varieties	*T. monococcum* var. *vulgare*	169–210 μ
	T. monococcum var. *Hornemanni*	154–196 μ
D. Immune varieties	*T. dicoccum, Khapli* 6400	210–252 μ
	T. dicoccam, Emmer 3933	168–182 μ

In group A, the distance between two vascular bundles is the longest and the number of thin-walled epidermal cells is the largest. In group B, they are less than in the group A. In group C, they are less than those in group B. In group D, in *T. dicoccum, Khapli,* the distance is great, and in *T. dicoccum, Emmer* it is short; these species being immune, these characters have no important significance.

As the results of the morphological studies, the characters, as shown in the following note were recognized on each variety of wheat. In the highly susceptible varieties, the number of epidermal hairs and thick-walled epidermal cells are scanty. In the resistant varieties, the number of hairs and the thick-walled epidermal cells are numerous. In the less susceptible varieties, the number of hairs are less than those of the resistant. In the immune varieties, no morphological differences could be found. On the whole it can be said that the degree of susceptibility to the powdery mildew of different varieties of wheat can be determined by their morphological characters.

(2) Difference of the infection spots.

The difference in the characters of the infection spots on *Triticum vulgare* (Ekishirazu), *T. turgidum* (Alaska), *T. compactum* (Hokkaido, Agr. Exp. Stat. No. 6355), *T. durum* (Belotourka), *T. monococcum* var. *Hornemanni, T. monococcum* var. *vulgare, T. dicoccum* var. *farrum* and *T. abyssinicum* were studied. In the highly susceptible varieties, as in *T. vulgare* (Ekishirazu), *T. Spelta, T. turgidum* and *T. compactum,* the affected leaves became greenish yellow in color within a month after infection. At that time, the circumference of the mycelial spot was fringed with a light green color. But in *T. vulgare* and *T. Spelta* these color changes did not so evidently appear. In the less susceptible varieties, the fringe of the light green color gradually turned to brown. In *T. monococcum* var. *vulgare* and *T. monococcum* var. *Hornemanni,* the brownish margin plainly appeared.

(3) Mechanical difference.

The phenomenon of plasmolysis was observed in the epidermal cells of the leaf of susceptible and immune varieties of wheat. The sugar solution of ½–3 mol was used for the measurement. The stripped epidermis of the leaf was mounted in a sugar solution and was observed under the microscope in the dark field. The results are shown in the following table:—

TABLE 33

Results of plasmolysis in the epidermal cells of the susceptible and immune wheat.

Varieties of wheat \ Sugar sol. Mol.	½	1	1½	2	3
T. dicoccum, Khapli	Did not appear	After 30 m.	After 18 m.	After 7 m.	Immediately
T. vulgare (Ekishirazu)	After 60 m.	After 10 m.	Immediately		

This experiment was made on wheat which had grown for a month after sowing. When 1.5 mol sugar solution was used, the

plasmolysis appeared immediately in *T. vulgare,* the susceptible variety, but in *T. dicoccum,* the immune variety, 3 mol solution had to be used to have a similar result.

(4) Chemical difference

a. Staining

The dyes are generally classed in the natural and artificial groups. For the latter group the author examined the reactions induced by the several basic and acid dyes in immune and susceptible varieties of wheat.

Acid dyes

1. Orange G. .... Clove-oil solution.
2. Bismarck brown .... Alcoholic solution.
3. Congo red .... Alcoholic solution.
4. Aceto Methyl blue.
5. Fuchsin .... Alcoholic solution.
6. Aceto Carmine.
7. Anilin blue .... Alcoholic solution.

Basic dyes

1. Crystal violet .... Alcoholic solution.
2. Giemsa's stain + NaOH
3. Methyl green .... Alcoholic solution.
4. Safranin .... Alcoholic solution.
5. Thionin .... Alcoholic solution.
6. Light green .... Alcoholic solution.

After 20–30 minutes from the treatment with the above dyes, the experimental material was observed under the microscope. When the stripped epidermis of *T. dicoccum, Khapli* was treated with Congo red the epidermal cells were not stained, while those of *T. vulgare* (Ekishirazu) were stained light red. When Bismarck brown was used, the epidermal cells of *T. dicoccum, Khapli* were stained orange in color, but those of *T. vulgare* stained light orange. When the other dyes were used, no difference could be recognized between the two varieties, both being stained to an equal degree and presenting a similar reaction.

b. Hydrogen-ion concentration

A. M. HURD (19, 20) reported on the relation of the hydrogen-ion concentration of the leaves and stems of the resistant and susceptible varieties of wheat to stem rust and other disease. She determined the H-ion concentration using expressed juice obtained from various parts of the leaves and stems in different growing stages. Her results are as follows:—

A. Seedlings 2 weeks old, limed soil.

		Cut 9 a.m. PH.	Cut 1 p.m. PH.
Khapli (R)	a	5.96	5.97
	b	6.92	
Little club (S)	a	6.00	6.04
	b	5.97	
Kanred (S)		6.04	a 6.13
			b 6.12
Turkey (S)		6.08	a 6.16
			b 6.13

B. Seedlings 5 weeks old, unlimed soil.

	Cut 9 a.m. PH.	Cut 1 p.m. PH.
Khapli (R)	5.97	5.98
Little club (S)	5.73	5.80
Turkey (S)	5.85	5.99

She noted that the hydrogen-ion concentration did not correlate on either resistant or susceptible characters. The present author used the method of J. SMALL (39, 40) (Hydrogen-ion concentration in plant cells and tissues, Chapter VIII). The following indicator solutions were used for the experiment.

Brom-thymol blue 0.02% (6.0–7.6)
  Mono Na. salt in 20% alcoholic solution.
Brom-cresol purple 0.04% (5.2–6.8)
  Mono Na. salt in 20% alcoholic solution.

Triticum vulgare (Ekishirazu), *T. durum* (Belotourka) and *T. dicoccum, Khapli* were sown on May 21. After 7 days, the H-ion concentration of the epidermal cells of the three varieties was measured. After that, they were measured for a month once every

five days. The H-ion concentration of the living protoplasm of the epidermal cells of the leaves could not be measured accurately because the protoplasm caused plasmolysis before the epidermal cells were stained to any perceptible extent. The thick-walled epidermal cells were more or less stained by the indicator solution, but the PH. value could not be very well determined on account of the cells being stained light in color. The guard-cells of the stomata were stained exceedingly well, and these cells are not infected by the powdery mildew.

The H-ion concentration of the haustoria in the epidermal cells was measured 10 minutes after the treatment by the solution. The PH. value was about 5.8–6.0. The PH. value of the conidia, germ tubes and mycelial hyphae was similar to that of the haustoria.

In addition, Methyl Red alcoholic solution (20%) was used as an indicator solution. The results were similar to those of the former experiments.

As the results of chemical tests, the difference of the epidermal cells of the susceptible and resistant varieties of wheat in regard to the staining reaction is that in *T. dicoccum, Khapli,* cells are not stained by Congo red, but they are stained orange color by Bismarck brown, and in *T. vulgare,* they are stained light red by Congo red and light orange by Bismarck brown. Also, the measurement of the hydrogen-ion concentration of the living protoplasm of the epidermal cells could not be determined by Small's method.

Summary of the section on specialization and resistance

1. The immune and susceptible characters of wheat to the infection by *Erysiphe graminis* f. sp. *Tritici* were determined by infection experiments. The characters differ more or less in different species and varieties. In susceptible varieties of wheat, the degree of susceptibility differs greatly in different varieties.

2. The highly or less susceptible characters are more or less changed by the environmental factors. In wheat cultivated in the field, the haustoria did not form in the thick-walled epidermal cells on both sides of the vascular bundles, but when the plants were grown in the laboratory, the haustoria were produced in those cells. The resistant characters of the protoplasm in the living cells did not change even though the plants were cultivated in Knop-solution of different hydrogen-ion concentrations. The osmotic pressure in the

epidermal cells of *T. vulgare* was lower than that of *T. dicoccum, Khapli.*

3. The susceptible and resistant varieties are distinguished by the difference in the morphological characters of the leaf. In the less susceptible variety, numerous hairs are produced on the surface of the leaves and the epidermis is composed of numerous thick-walled cells. The highly susceptible variety has less hairy epidermis, whose wall is much thinner to a great extent. But, in the immune varieties, no significance could be assigned to the morphological characters as in the cases of the resistant and susceptible varieties.

4. In the course of the infection experiments, the writer found that the conidia on *T. vulgare* (Ekishirazu) did not infect *T. monococcum* var. *Hornemanni* unless they were passed through *T. dicoccum* var. *farrum*. *T. dicoccum* var. *farrum* proved to be a bridging species.

Systematic Part

Erysiphaceae are to be found widely throughout the tropical and temperate zones. In this country, which ranges from Lat. 21°45′ N. to Lat. 50°55′ N. numerous species have been found. For the investigation of both the conidial and perithecial stages of the fungi, Sapporo in the island of Hokkaido is most favorably situated.

The species reported in the present paper are as follows:

Erysipheae	Cystotheca	2 species
	Sphaerotheca	6 species
	Podosphaera	4 species
	Erysiphe	7 species
	Uncinula	23 species
	Typhulochaeta	1 species
	Sawadaea	3 species
	Microsphaera	17 species
Phyllactinieae........	Phyllactinia	9 species
	Uncinulopsis	1 species
Leveilluleae..........	Leveillula	1 species
	Total	74 species

Among the above species, those considered as new species are nine in number; namely, *Microsphaera Ligustri* HOMMA on *Ligustrum ovalifolium; M. Coryli* HOMMA on *Corylus heterophylla* var. *japonica*, *Corylus mandshurica* and *Corylus Sieboldiana*; *M. Abeliae* HOMMA on *Abelia spatulata*; *M. Viciae-unijugae* HOMMA on *Vicia unijuga* and *Vicia Tanakae; Sawadaea Negundinis* HOMMA on *Acer Negundo*; *Uncinula bifurcata* HOMMA on *Quercus serrata*; *U. Picrasmae* HOMMA on *Picrasma quassioides*; *U. Betulae* HOMMA on *Betula Ermanii* var. *subcordata,* and *Betula Tauschii*; and *U. Nishidana* HOMMA on *Sterculia platanifolia*; those species whose names are revised by the new combination are six; viz., *Sphaerotheca japonica* (SALM.) HOMMA, *Sawadaea Tulasnei* (FUCK.) HOMMA, *Microsphaera pseudo-Lonicerae* (SALM.) HOMMA, *Phyllactinia Fraxini* (DC.) HOMMA, *Phyl. Pyri* (Cast.) HOMMA, and *Phyl. quercus* (MÉR.) HOMMA.

The genus Typhulochaeta is the only endemic genus in this country, and *Typhulochaeta japonica* is found widely in Honshu and Kyushu.

The total number of the specimens examined by the present author is 3090, of which those belonging to Cystotheca are 142, to Sphaerotheca 615, to Podosphaera 93, to Erysiphe 872, to Uncinula 391, to Typhulochaeta 14, to Sawadaea 92, to Microsphaera 559, to Phyllactinia 282, to Uncinulopsis 27, and to Leveillula 3. The host plants of these specimens belong to 427 species. A large number of these specimens of the Erysiphaceae of Japan which are preserevd in the Herbarium of our University were kindly placed in the writer's hand by Prof. K. MIYABE for the preparation of the present paper.

The powdery mildews parasitic on Humulus, Acer, Lamium, Galeopsis and Lithospermum were first recorded under the collective name of *Mucor Erysiphe* by LINNAEUS in his "Species Plantarum" in 1753 (106). Later, A. P. DE CANDOLLE (58), E. FRIES (66), L. H. LÉVEILLÉ (101), and others classified them into many genera by the characters of the perithecial stages. In 1870, A. DE BARY (5) reported the result of his studies on the parasitism of Erysiphaceae. The species belonging to this family were found to send haustoria into the epidermal cells of host plants. At that time, mycologists recognized them as external parasites. But in 1899, E. PALLA (25) investigated the parasitism of the genus Phyllactinia, in which he found special hyphal branches from the creeping mycelium entering into the intercellular spaces of the mesophyll tissue of the leaf through the stomata. The inner hyphae send haustoria into the surrounding parenchyma cells. By these characters, the family Erysiphaceae was divided into two subfamilies of Erysipheae and Phyllactinieae. In 1900, E. S. SALMON (32) published his monograph of Erysiphaceae, in which he followed the opinion of PALLA.

On the other hand, in 1809, the genus Oidium was first established as a member of Mucedinaceae by H. F. LINK. (104). In 1817, Oidium on grass was included in the genus Acrosporium by C. G. NEES (121). In 1824, LINK (105) published several new species in Oidium. In 1829, E. FRIES (66) noted eight species of Oidium in which he recognized *Oidium leucoconium* as the conidial stage of *Erysiphe pannosa* and also *Oidium Erysiphoides* as that of many other species of Erysiphaceae. This report is the first record on the relation of the conidial and perithecial stages of Erysiphaceae. In 1837, M. A. LIBERT recognized *Oidium monilioides* LINK as the conidial stage of *Erysiphe graminis*.

In 1880, P. A. SACCARDO (137) emended the characters of Oidium LINK in Michelia II, p. 15. In 1886, the same author (138) enume-

rated 37 species of Oidium which were divided into two groups, according to the size of the spores, viz. Microsporae and Macrosporae. According to him, the species belonging to Macrosporae include only the conidial stages of Erysiphaceae. In 1907, G. LINDAU (103) noted twenty European species of Oidium, most of which he considered as the conidial stages of Erysiphaceae.

As to the conidial stage of *Phyllactinia corylea*, L. R. and C. TULASNE (177) remarked in 1861 that it must be separated from Oidium because of morphological differences. In 1900, N. PATUILLARD and P. HARIOT (128) established the new genus Ovulariopsis, on the ground that the conidia are clavate and are produced in a chain or solitary on the apex of the conidiophore. *Ovulariopsis erysiphoides* was described as the conidial stage of *Phyllactinia corylea*. On the form of Ovulariopsis occurring on *Morus alba*, in 1903, G. DELACROIX (7) recognized a new species and described it under the name of *Ovulariopsis moricola*. In 1904, E. S. SALMON (144) noted that *Ovul. erysiphoides* and *Ovul. moricola* belong to the conidial stage of *Phyllactinia corylea*. But, at the present time, *Ovul. moricola* is recognized as the conidial stage of *Phyllactinia moricola*.

In 1902, G. SCALIA (155) described Oidiopsis as a new genus of Mucedinaceae. This genus like Ovulariopsis is a perfect inner parasite, the mycelial hyphae spreading in the intercellular spaces of the mesophyll tissue of the leaves and forming haustoria in the surrounding cells. The conidiophores are produced as branches from the inner mycelium coming out through the stomata and there forming conidia on their apices. *Oidiopsis sicula* on *Asclepias curassavica* was described by SCALIA as a new species representing his new genus. In 1905, SALMON (146) studied the conidial stage of *Erysiphe taurica*, and recognized that it belongs to Oidiopsis. In the next year, the same author (147) transferred the genus Oidiopsis from Mucedinaceae to Erysiphaceae, on which he founded a new subfamily Oidiopsideae. *Erysiphe taurica* was thus renamed *Oidiopsis taurica*. Erysiphaceae have been divided by him into three subfamilies, Erysipheae, Phyllactinieae and Oidiopsideae. In 1914, K. SAWADA (149) tried to classify the Erysiphaceae of Formosa by the characters of their conidial stage. In 1921, G. ARNAUD (49) announced that Oidiopsis is the generic name proposed for the conidial stage, and should not be used for the perfect perithecial stage. For this reason, he proposed Leveillula as the name of the genus.

At the present time, the relation of the perithecial and conidial stages of Erysiphaceae is as follows:

	Perithecial stage		Conidial stage
	Erysiphaceae		Mucedinaceae
Subfam.	Erysipheae	Genus	Oidium
,,	Phyllactinieae	,,	Ovulariopsis
,,	Leveilluleae	,,	Oidiopsis

Historical survey of the Japanese Erysiphaceae

Cystotheca Wrightii parasitic on an evergreen oak was described by BERKELEY and CURTIS in 1858 (50). This was the first record of the Japanese Erysiphaceae. It was collected in the Loo-Choo Islands by CHARLES WRIGHT in April 1855, in the North Pacific Exploring Expedition under Commodore Rodgers.

In 1887, E. TANAKA (170) noted on the parasitic fungi in general, and he used therein for the first time the name "Udonko", meaning the "floury powder", for the powdery mildew in this country. In 1890, *Cystotheca Wrightii* on *Quercus myrsinaefolia* (Shira-kashi) was referred to by the same author (171) in his paper published under the name of "On the collection of fungi".

In 1891, K. SHIRAI (157) noted on the Koshu-grape mildew disease (*Oidium Tuckeri*) which had appeared in the vicinity of Katsunuma in the province of Kai. In 1892, the same author (158) reported the powdery mildew of *Nicotiana Tabacum* in his publication on the parasitic diseases in Saitama Prefecture. In 1897 Sphaerotheca on *Arctium Lappa* was noted by the same author (159).

In 1901, S. KUSANO (197) studied the haustoria of the powdery mildew, and he said that the common powdery mildew send haustoria into the epidermal cells of the host plants, while in the genus Phyllactinia, the mycelium spreads in the intercellular space among the mesophyll cells of the leaf and it has a tendency to approach the vascular bundles, owing to the phenomenon of chemotropism. In 1902, the same author (98) recorded that the conidia of the powdery mildew may pass the winter in the warmer region in the Province of Izu. In the same year, he (99) wrote on *Cystotheca Wrightii* parasitic on *Quercus glauca* (Aragashi) in his paper on "The parasitic fungi collected in the Chugoku district".

In 1900, E. S. SALMON (32) published "The monograph of Erysiphaceae", in which the species attributed to Asia are 25 in number and the varieties 3. The Japanese species and varieties therein mentioned are as follows: *Podosphaera Oxyacanthae, P. Oxyacanthae* var. *tridactyla, P. leucotricha*; *Sphaerotheca Humuli, S. Humuli* var. *fuliginea*; *Uncinula Salicis, U. Salicis* var. *Miyabei* (n. var.), *U. Aceris, U. clandestina, U. necator, U. Clintonii, U. polychaeta, U. australiana, U. Fraxini* (n. sp.), *U. Sengokui* (n. sp.); *Microsphaera Berberidis, M. Alni, M. grossulariae; Erysiphe Polygoni, E. Cichoracearum, E. Galeopsidis, E. graminis; Phyllactinia corylea.* There are 2 new species and 1 new variety. Most of these Japanese materials had been sent by Prof. MIYABE to Prof. SALMON. In the same year, (141) a species of Uncinula on *Quercus glandulifera* was first described as *Uncinula septata* SALM. In the same year too, "The Erysiphaceae of Japan" was published by SALMON (142). The materials were sent from Prof. K. MIYABE and Dr. S. HORI to him. The species included in that paper were:

Erysiphe 4 species; Podosphaera 2 species, 1 variety; Sphaerotheca 1 species, 1 variety; Microsphaera 3 species; Uncinula 6 species, 1 variety; and Phyllactinia 1 species. The total number is 17 species and 3 varieties. In 1905, the same author (145) published "The Erysiphaceae of Japan, II". In this paper, he made an enumeration of the former materials, as well as the specimens which had been subsequently sent to him from Prof. K. MIYABE, Dr. S. HORI, Dr. S. KUSANO, Mr. N. NAMBU and Mr. Y. TAKAHASHI. The species and varieties of the new materials are as follows:

Podosphaera 1 species, 1 variety; Sphaerotheca 2 species, 1 variety; Erysiphe 4 species; Microsphaera 3 species; Uncinula 12 species; and Phyllactinia 1 species. The total number is 23 species and 2 varieties. The host plants numbered 94 species. The species which were included in "The Erysiphaceae of Japan, III" by SALMON (148) in 1908 are as follows:

Podosphaera 2 species; Sphaerotheca 2 species, 2 varieties; Erysiphe 4 species; Microsphaera 3 species, 3 varieties; Uncinula 14 species; and Phyllactinia 1 species.

The total number is 26 species and 5 varieties. The new species and varieties therein described are *Uncinula simulans, Sphaerotheca Mors-Uvae* var. *japonica, Microsphaera Alni* var. *Yamadai* and *M. Alni* var. *pseudo-Lonicerae.* In 1902, the "Supplemental notes on

the Erysiphaceae" was published by the same author (143). He discussed in it the several species of *Uncinula* and *Sphaerotheca* of Japan.

In 1900, P. and H. SYDOW (165) published the "Fungi novi Japonici", in which they reported on *Uncinula Kusanoi* n. sp. and *Oidium japonicum* n. sp. In 1909, the same authors (166) noted on *Erysiphe Polygoni, Uncinula Miyabei, U. Salicis* and *Phyllactinia corylea* in the "Micromycetes japonici". In 1913, in the paper entitled "Ein Beiträge zur Kenntnis der parasitischen Pilzflora des nordlichen Japan", 12 species and 1 variety of Erysiphaceae were reported by the same authors (165). *Uncinula Salmoni* SYDOW is a new species. In 1914, the same authors (168) published "Zweiter Beiträge zur Kenntnis der parasitischen Pilzflora des nordlichen Japan". In this paper, they noted on *Microsphaera Yamadai* n. comb., *Uncinula Delavayi* and *Cystotheca lanestris*. The above materials which were reported by SYDOW are specimens which were sent to them by Mr. M. MIURA.

In 1901, P. HENNINGS (77) published "Fungi japonici, I.", reporting in it on *Erysiphe communis, Microsphaera japonica* (n. sp.), *Sphaerotheca Castagnei* and *Phyllactinia suffulta* var. *moricola* (n. var.). In 1902, the same author (78) published his "Fungi japonici, II". The species reported therein are as follows: *Sphaerotheca Kusanoi* (n. sp.), *Sph. Phteirospermi* (n. sp.), *Sph. Humuli; Erysiphe Polygoni, E. Pisi* var. *Desmodii* (n. var.); *Microsphaera sambucicola* (n. sp.); *Uncinula Shiraiana* (n. sp.), *U. Zelkowae* (n. sp.), *U. clandestina* form. *japonica* (n. form.), *U. Salicis, U. verniciferae* (n. sp.); *Phyllactinia suffulta.* The above two papers are reports on specimens which had been sent to Prof. HENNINGS from Prof. K. SHIRAI. In 1903, 2 species of Erysiphe, 2 species of Uncinula, 1 species of Microsphaera and 1 species of Phyllactinia were reported in "Fungi japonici, III" by P. HENNINGS (79). In 1905, the same author (80) noted on *Sphaerotheca Castagnei, Erysiphe Cichoracearum, E. Polygoni, Microsphaera Mougeotii, Uncinula Clintonii* and *Phyllactinia suffulta* in "Fungi japonici, V".

In 1902, T. NISHIDA (124) wrote on *Uncinula Salicis, U. polychaeta* and *Phyllactinia corylea* in "The list of fungi collected in the Etchu Province".

In 1904, N. NAMBU (119) reported on *Microsphaera Alni, Uncinula Kusanoi, U. Aceris* and *Phyllactinia corylea* in "The parasitic fungi collected in the vicinity of Tokyo". In 1906, the same author

(120) published a paper under the name of "A list of parasitic fungi", in which he reported on *Sphaerotheca Humuli, Erysiphe Cichoracearum, Microsphaera Alni, Uncinula septata* and *Oidium erysiphoides.*

In 1901, T. YOSHINAGA (181) noted on *Cystotheca Wrightii, Erysiphe Polygoni, Phyllactinia suffulta* and *Oidium erysiphoides* in "Some fungi from Tosa Province". In 1904 (182), he published the third part of the above paper, in which *Sphaerotheca Castagnei, Microsphaera Mougeotii* and *Uncinula Clintonii* were described.

In 1905, K. YOSHINO (183) reported the following species:

Sphaerotheca 2 species, 1 variety; Podosphaera 1 species; Erysiphe 3 species; Microsphaera 1 species; Uncinula 4 species; Phyllactinia 1 species; and Cystotheca 1 species.

In 1907, I. MIYAKE (115) described *Uncinula Mori* (n. sp.) parasitic on *Morus bombycis.*

In 1914, a paper under the title of "Studies on the Oidium stages of Erysiphaceae" was published by K. SAWADA (149). In this paper, he published the new genus Sawadaea MIYABE, and he attempted the classification of Erysiphaceae according to the characters of the conidial stage. *Erysiphe Polygoni* was changed to the name *Microsphaera Polygoni,* and *Oidium subspiralis* SALM. was proved to be the conidial stage of *Phyllactinia subspiralis* (SALM.) SAWADA. In 1916, *Phyllactinia subspiralis* was separated from the genus Phyllactinia, and a new genus *Uncinulopsis* was established (151). In 1919, the same author (152) published his "Desc. catalog. Formosan fungi". He therein described 14 species, among which there was 1 new species, *Erysiphe Cinnamomi* SAWADA. In 1927, "Studies on the Oidium stages of Erysiphaceae in Formosa" was published by the same author (153). In this paper, he recorded 6 new species, *Erysiphe Tabaci, E. Plantaginis, Oidium Leonuri-sibiricae, Oid. Leucas-javanicae, Oid. Lactucae-debilis* and *Oid. Sonchi-arvensis,* and also made notes on *Erysiphe graminis* and *Oid. crystallinum.* In 1930, a paper "On the systematic investigation of Phyllactinia in Formosa" was published by the same author (38), in which he described 6 new species and 1 new combination of Phyllactinia, and 9 new species of Ovulariopsis. These species are as follows: *Phyllactinia Actinidiae-latifoliae, Phyll. Actinidiae-formosanae, Phyll. Broussonetiae-Kaempferi, Phyll. Sapi, Phyll. kakicola, Phyll. Pyri-serotinae, Phyll. moricola, Ovulariopsis Alni-formosanae, Ovul. Asclepiadis-curassavicae, Ovul. Ampelopsidis-heterophyllae, Ovul. Ampelopsidis-ciliatae, Ovul.*

Cephalanthi, Ovul. Caricae, Ovul. Macarangae, Ovul. Salicis- Warburgi, and *Ovul. Broussonetiae-papyriferae.* In 1933, SAWADA (154) published 1 species of Uncinula, 7 species of Phyllactinia, 2 species of Oidiopsis, 5 species of Oidium and 9 species of Ovulariopsis in Formosa. Amongst these species, *Oidiopsis Capsici, Oidiop. Papaveris, Oidium Emiliae-sonchifoliae, Oid. Heliotropii-indici, Oid. Cephalanthi,* and *Oid. Rosae-indicae* were added as new to science.

In 1915, S. ITO (89, 90) published a paper under the title of the "On Typhulochaeta, a new genus of Erysiphaceae", in which *Typhulochaeta japonica* S. ITO and HARA parasitic on *Quercus serrata* was described as a new species.

In 1915, K. HARA (73) reported on *Typhulochaeta japonica, Uncinula septata* var. *curvispora* (n. var.), *U. geniculata* var. *carpinicola* (n. var.), *U. necator* var. *Actinidiae* (n. var.), and *Microsphaera Alni* forma *Quercus-glanduliferae* (n. form.). In 1919, C. TANAKA (173) published the diagnoses in English of HARA's new species and varieties, viz. *Uncinula curvispora, U. geniculata* var. *carpinicola, U. necator* var. *Actinidiae* and *Microsphaera Alni* form. *Quercus-glanduliferae.* In 1921, K. HARA (74) reported on *Microsphaera Euonymi-japonicae* (SALM.) HARA.

In 1924, K. TOGASHI (174) noted 6 species of *Erysiphaceae* in "Fungi collected in the Islands of Rishiri and Rebun, Hokkaido".

Erysiphaceae LÉV.

The species of this family are parasitic on living flowering plants. Hyphae are usually white or sometimes brown colored, septate, branched and much interwoven as superficial mycelium. This family is divided into three subfamilies by the character of the parasitism. They are Erysipheae, Phyllactinieae, and Leveilluleae. In Erysipheae, the mycelium is superficial, sending haustoria into the epidermal cells of the host plants. In Phyllactinieae, the mycelium is subsuperficial, passing mycelial branches through the stomata into the intercellular spaces of the mesophyll, sending haustoria into the parenchyma cells, and forming conidia and perithecia on the superficial mycelium. In Leveilluleae, the mycelium is endophytic, forming haustoria in the surrounding cells of the leaf

tissue, forming conidia on the conidiophores issuing from the stomata and forming perithecia on the superficial mycelium.

Conidia (Oidium, Ovulariopsis and Oidiopsis) are produced concatenately; they are large, one-celled, hyaline, ellipsoidal or clavate, borne on the conidiophores which branch either from the external or internal hyphae; conidiophores are hyaline, simple, thin walled, erect or bent at the base.

Perithecia are sessile, single, seated on the mycelium, membranaceous, at first colorless, then yellow, finally becoming dark brown, globose or globose-depressed, sometimes concave or lenticular, with walls several-layered; appendages arising from special, equatorial or basal portion of the perithecium, and they are either similar to the mycelial hyphae or different showing definite forms, colorless or brown. Asci are produced singly or in groups from the base of the perithecial cavity; they are colorless, subglobose, oblong or ovate, usually pedicellate. Ascospores are simple, colorless, ellipsoidal or ovate, thin-walled, each ascus holding 2–8 spores. Paraphyses absent.

Subfam. Erysipheae PALLA

Mycelium is wholly ectophytic, sending haustoria into the epidermal cells of the host plants. Conidia (Oidium) are produced in a chain on conidiophores arising from the external hyphae.

Key to the genera of the subfam. Erysipheae

1. Ascus single 2
   Asci several 3
2. Special hairs produced from the creeping brown mycelium, appendages wanting or very scarce, matured conidia produced in a chain, barrel-shaped .... *Cystotheca* (288)
   Appendages simple and hypha-like, matured conidia arise in a chain, elongate-ellipsoidal .... *Sphaerotheca* (295)
   Appendages dichotomously branched at the apex, matured conidia arise in a chain, subglobose or ellipsoidal .... *Podosphaera* (313)
3. Appendages simple 4
   Appendages branched 5
4. Appendages more or less like the mycelial hyphae, matured conidia produced solitary or in a chain .... *Erysiphe* (320)
   Appendages uncinulate at the apex, matured conidia solitary.... *Uncinula* (343)
   Appendages clavate, conidia not yet known .... *Typhulochaeta* (369)
5. Appendages simple, dichotomously or trichotomously branched, uncinulate at the apex, matured conidia arise in a chain and have two forms... .... *Sawadaea* (370)
   Appendages dichotomously branched several times at the apex, matured conidia solitary .... *Microsphaera* (376)

Cystotheca BERK. & CURT.

Mycelium is hypophyllous, superficial and persistent, grayish or blackish brown colored when matured, producing hairy branches from the mycelium; haustoria are formed in the epidermal cells; matured conidia are produced in a chain, barrel-shaped; perithecia are subglobose and brown in color, composed of two layers, which are easily separated from each other when pressed; asci are solitary; spores are 6–8 in number. This genus includes 2 species.

The present genus was first described by BERKELEY and CURTIS (50) in "Characters of new fungi, collected in the North Pacific Exploring Expedition by CHARLES WRIGHT". It is represented by a single species of *Cystotheca Wrightii.* The type specimen was collected in the Loo-Choo Islands in April 1855 (coll. no. 422). The genus was included in *Perisporiaceae.* In this report nothing was noted on the host plant of this specimen, but fortunately a part of the type specimen, which was kindly given by Dr. FARLOW to Dr. MIYABE, has been preserved in our Herbarium. In addition, the sketches of the original type preserved in the CURTIS collection in the FARLOW Herbarium, which were drawn by Prof. S. ITO, were kindly placed in the author's hand. Judging from these materials, the host plant of this specimen is evidently *Quercus stenophylla* BL. although a co-type which is deposited in Kew Herbarium was erroneously identified as *Quercus acuta* by v. HÖHNEL (178). The present genus was also included in Perisporiaceae by SACCARDO (138) and ENGLER (64).

On the other hand, in 1886, HARKNESS described *Sphaerotheca lanestris* parasitic on a deciduous oak, *Quercus agrifolia* NÉE. In 1900, SALMON gave a full description and observation on *Sph. lanestris* in his Monograph of Erysiphaceae.

In 1901, P. HENNINGS (77) gave a full account of *Cystotheca Wrightii* on *Quercus myrsinaefolia* collected in the Tokyo Bot. Gard. in Dec. 1897, by KUSANO. HENNINGS recognized it as a new family under the name of Cystothecaceae, by the presence of a peculiar cellular sac enveloping a single ascus.

In 1909, *Sphaerotheca lanestris* was transferred to the genus Cystotheca under the name of *Cystotheca lanestris* (HARK.) by Dr. MIYABE, and it was published by IDETA (87) in Japanese Phytopathology p. 226 (Japanese).

In 1911, SACCARDO (140) too renamed it as *Cystotheca lanestris* (HARK.) SACC.

In 1912, v. HÖHNEL (178) noted that "Die Gattung *Cystotheca* mit *Sphaerotheca* zusammenfällt, *Cystotheca* ist daher eine *Erysiphee* und die Aufstellung der Familie der Cystothecaceen ist eine irrtümliche. Diese meine Angaben wurden durch die Untersuchung des Original-Exemplares von *Cystotheca Wrightii* aus dem Herbarium in Kew, die ich 1909 vornahm, völlig bestätigt. Ich nannte nun den Pilz *Sphaerotheca Wrightii* (BERK. et CURT.), v. H.".

In 1915, SAWADA (150) discussed this genus in the Transactions of the Sapporo Nat. Hist. Soc. V, p. 204–209 (Japanese). According to his paper, the conidia are of Oidium type, including the well-developed fibrosin bodies, the inner wall of the perithecium easily separates from the outer, the appendages are produced from the basal portion of the perithecium, and 8 spores are included in an ascus. Because of these characters, he insists that Cystotheca must be included in Erysiphaceae and treated as synonymous to Sphaerotheca.

In 1917, the genus Cystotheca was included in Sphaerotheca as its synonym, by THEITZEN and SYDOW (173).

On the comparison of *Sphaerotheca lanestris* and *Cystotheca Wrightii*, the mycelial hyphae are seen to be densely compacted in both species, grayish to blackish brown in color and the haustoria are subglobose, extending into the epidermal cells; the matured conidia are produced in a chain; and they have special hairy bodies branched from the creeping mycelium; appendages on the perithecia are either completely lacking or sparingly produced, besides the inner wall of the perithecium easily becomes free from the outer. As these two species have these characters in common, the author has come to the conclusion that they must be included in the same genus. In the two genera Cystotheca and Sphaerotheca, in the form of the conidia, the former is of a barrel shape and the free end of the apical conidium has a tendency to become apiculate or obtusely pointed, while the latter is ellipsoidal; besides, in Cystotheca, numerous special hairs are produced from the creeping mycelium throughout all stages, and in Sphaerotheca such hairs are never seen. The inner perithecial wall of Cystotheca becomes very easily separated from the outer, and appendages are lacking or very scanty.

From the above mentioned differing characters, we have come to the conclusion that the genus Cystotheca ought to be kept distinct from Sphaerotheca.

The genus Cystotheca is allied to Perisporiaceae in respect to the fact that the special hairs are abundantly produced from the creeping mycelium and the mycelia of *Cystotheca Wrightii* are blackish brown in color, but the other characters coincide with Erysiphaceae rather than with Perisporiaceae.

Key to the species of the genus Cystotheca

1. Mycelium and hairs dark chocolate brown or blackish brown colored when mature, and parasitic on evergreen orks.................. **C. *Wrightii*** (291)
2. Mycelium and hairs grayish brown colored when mature, and parasitic on deciduous oaks..**C. *lanestris*** (292)

Cystotheca Wrightii BERK. & CURT.

(Pl. VII. figs. 1, 2)

Proceed. Amer. Acad. IV, p. 130, 1858–1859; SACC. Syll. Fung. I, p. 72, 1882, XVI, p. 407, 1902, and Ann. Myc. VIII, p. 343, 1910; P. HENN. in ENGL. Bot. Jahrb. XXVIII, p. 273, 1901. (TANAKA, Bot. Mag. Tokyo, IV, p. 298, 1890; Ideta, Pract. Phytopath. p. 170, 1901, and Jap. Phytopath. p. 226, 1911; KUSANO, Bot. Mag. Tokyo, XVI, p. 203, 1902; YOSHINAGA, Bot. Mag. Tokyo, XVIII, p. 31, 1904; YOSHINO, Bot. Mag. Tokyo, XIX, p. 207, 1905; SHIRAI, List, p. 28. 1905; SHIRAI & MIYAKE, List, p. 191, 1917).

Syn. *Sphaerotheca Wrightii* (BERK. & CURT.) v. HÖHNEL, Zeitsch. f. Gärungsphys. I, p. 46, 1912. (SHIRAI & HARA, List, p. 371, 1929).

Sphaerotheca Wrightii (BERK. & CURT.) HARA, Dendropath. p. 4, 1923.

Sphaerotheca phytoptophila (not KELL. & SWING.) TAI et WEI Sinensia, III, p. 99, 1932.

Oidium japonicum SYD. Mém. d. l'Herb. Boiss. p. 6, 1900.

Hypophyllous, mycelium persistent, forming dense mass, at first pale brown in color, gradually turning to dark chocolate brown, producing sickle-shaped hairs; matured conidia borne in a chain, barrel-shaped, swollen at the center, the free end of the terminal one obtusely pointed, including the well-developed fibrosin bodies, 25.2–36.0 × 15.6–22.8 μ; perithecia gregarious, deep brown colored, imbedded in the mycelial mass, 62.4–72.0 μ in diameter, inner wall is easily separated from the outer, colorless and formed of large hexagonal cells, 13.2–18.0 × 12.0–15.6 μ, outer wall cells 15.6–18.0

× 9.6–14.4 μ in size; appendages none; ascus 1, subglobose or ellipsoidal, stalked, hyaline, 76.8–91.2 × 54.4–57.6 μ; spores 6–8 in number, ellipsoidal, 19.2–24.0 × 12.0–15.6 μ.

Hab. On leaves of *pasania cuspidata* OERST. (Shii). Honshu—Sagami.

On *Quercus acuta* THUNB. (Aka-gashi). Honshu—Musashi. Shikoku—Iyo.

On *Quercus glauca* THUNB. (Aragashi). Honshu—Musashi, Kazusa, Awa, Sagami, Suruga, Izu, Shinano, Mino, Yamashiro, Settsu, Bizen, Aki, Inaba. Kyushu—Buzen, Hizen, Higo. Loo-Choo Isl.—Hanechi, Yaeyama. Formosa—Daihoku.

On *Quercus myrsinaefolia* BL. (Shira-kashi). Honshu—Rikuzen, Musashi, Hitachi, Kozuke, Echigo, Mino, Bizen, Inaba. Kyushu—Higo.

On *Quercus stenophylla* MAKINO (Urajiro-gashi). Honshu—Musashi. Loo-Choo Isl.—(Apr. 1855, C. WRIGHT, U. S. Pac. Ex. no. 422, type).

Distrib. Japan (Honshu, Shikoku, Kyushu, Loo-Choo and Formosa) and China.

Remarks. *Cystotheca Wrightii* on *Quercus stenophylla* was first collected in this country by CHARLES WRIGHT in the Loo-Choo Islands in 1855. It was the first record of Erysiphaceae from Japan.

This species is parasitic on ever-green oaks and is very common in the warmer parts of this country. This fungus can be recognized at a glance by the dark chocolate-brown colored mycelial mass, which appears on the under surface of the leaves of the host plants. By this mycelial color, it is easily distinguished from *Cystotheca lanestris*. Besides the mycelial hairs are deeper brown and broader in width, assuming a sickle shape.

In 1912, this species was transferred to *Sphaerotheca* by v. HÖHNEL (178). In 1923, K. HARA (75) without knowing of v. HÖHNEL's action, also renamed it *Sphaerotheca Wrightii*. Truly, in a certain species of Sphaerotheca, as in *Sph. Mors-Uvae*, the mycelium assumes a dark brown color as in the case of Cystotheca, and they are both monoascus. But, in Sphaerotheca special shaped hairs are never found on the mycelium and the inner perithecial wall is not easily separated from the outer as it is in Cystotheca, in which appendages are either entirely wanting or very rarely present. Besides they are distinguishable from each other by the forms of their conidia.

From the above mentioned characters, the present author considers it better to retain this fungus in Cystotheca than to transfer it into Spaerotheca.

Cystotheca lanestris (HARKN.) MIYABE

(Pl. VII, fig. 3)

In IDETA, Jap. Phytopath. p. 226, 1909; MIYAKE, Bot. Mag. Tokyo, XXVII, p. 40, 1913.

Syn. *Sphaerotheca lanestris* HARKN. New Calif. Fungi, p. 20, 1886; TRACY and GALLOWAY, Journ. Myc. IV, p. 34, 1888; SACC. syll. Fung. IX, p. 364, 1891; ELL. & EVERH. N. Amer. Pyren. p. 9, 1892; SALM. Monogr. Erysiph. p. 74, 1900, and Bull. Torr. Bot. Club, XXIX, p. 95, 1902. (SALM. Ann. Myc. III, p. 252, 1905, and VI, p. 11, 1908; SHIRAI, List, p. 94, 1905; SHIRAI & MIYAKE, List, p. 627, 1917; SAWADA, Agr. Exp. Stat. Formosa, Bull. XIX, p. 159, 1919; IDETA, Jap. Phytopath. (Suppl. I) p. 204, 1925; SHIRAI & HARA, List, p. 371, 1927).

Sphaerotheca Kusanoi P. HENN. & SHIRAI, in ENGL. Bot. Jahrb. XXIX, p. 147, 1901; SACC. Syll. Fung. XVI, p. 402, 1902. (SHIRAI, List, p. 94, 1905; SHIRAI & MIYAKE, List, p. 627, 1917).

Cystotheca tenuis MIYABE & TAKAHASHI, in IDETA, Pract. Phytopath. p. 170, 1901. (Shirai, List, p. 28, 1905; SHIRAI & MIYAKE, List, p. 191, 1917).

Cystotheca lanestris (HARKN.) SACC. Ann. Myc. IX, p. 249, 1911; SACC. Syll. Fung. XXII, p. 20, 1913. (SYD. Ann. Myc. XII, p. 161, 1914).

Oidium ventricosum HARKN. New Calif. Fungi, p. 20, 1886; SACC. Syll. Fung. IX, p. 364, 1891.

Hypophyllous, mycelium persistent, forming dense mass, grayish brown in color, the mycelial hyphae 4.8–5.6 μ in width, the mycelial hairs slender, flexuous and long; matured conidia produced in a chain, barrel-shaped and the free end of the apical one is rounded or obtusely pointed, granulate, vacuolate, including the well-developed fibrosin bodies, 26.4–36.0 $\times$ 12.0–22.8 μ in size; perithecia globose, 98.0–108.0 μ in diameter; cells, those of the inner wall 12.0–16.8 μ, the outer wall 12.0–14.4 μ, the inner wall is composed of hexagonal cells, hyaline, and the outer wall dark brown in color; appendages scanty, interwoven with the mycelial hyphae, or hyaline or pale brown in color, frequently wanting; ascus 1, elongate-ellipsoidal, with a short stalk, 116.0–130.0 $\times$ 70.8–74.4 μ; spores always 8, ovate or ellipsoidal, 22.8–27.5 $\times$ 13.2–15.2 μ.

Hab. On leaves of *Quercus acutissima* CARR. (Kunugi). Honshu—Tamba.

On *Quercus aliena* BL. (Nara-gashiwa). Kyushu—Higo.

On *Quercus crispula* BL. (Mizunara). Hokkaido—Ishikari. Honshu—Uzen, Shimozuke, Suruga. Kyushu—Bungo, Higo.

On *Quercus dentata* THUNB. (Kashiwa). Hokkaido—Ishikari. Honshu—Rikuchu.

On *Quercus major* NAKAI (Oba-konara). Hokkaido—Ishikari.

On *Quercus serrata* THUNB. (Konara). Hokkaido—Oshima, Iburi, Ishikari. Honshu—Mutsu, Rikuchu, Rikuzen, Ugo, Iwaki, Hitachi, Musashi, Kazusa, Kozuke, Sagami, Echigo, Etchu, Kaga, Suruga, Izu, Shinano, Tamba, Settsu, Mimasaka, Oki. Shikoku—Iyo.

Distrib. Japan (Hokkaido, Honshu, Shikoku and Kyushu), and North America.

Remarks. The present species was first described as *Sphaerotheca lanestris* by HARKNESS in 1886. SALMON, ELLIS and EVERHART used this specific name. In 1902, P. HENNINGS (78) named it as *Sph. Kusanoi* P. HENN. & SHIRAI, from a specimen which was collected by KUSANO on Mt. Myogi, in Prov. Kozuke, on *Quercus serrata*. Although it was not possible for the present writer to examine its authentic specimen, it was possible to study this species parasitic on the same host, from specimens that had been collected in every part of this country. All the specimens thus examined had similar characters and were found to be identical with *Cyst. lanestris*. In 1901, MIYABE and TAKAHASHI described it (in manuscript) as *Cystotheca tenuis* parasitic on *Quercus crispula* and *Q. acutissima*, and it was published by IDETA (86) in his Practical Phytopathology (Japanese), not accompanied by a diagnosis of the fungus. In 1909, *Sphaerotheca lanestris* was transferred to the genus Cystotheca by MIYABE (87) and it was called *Cystotheca lanestris* (HARKN.) MIYABE. This name was published by Ideta in his Japanese Phytopathology in the same year. In 1911, SACCARDO (140) used the same name *Cystotheca lanestris* (HARKN.) SACC. for the fungus, based on the character of the perithecium, the inner wall of which can be separated readily from the outer.

On the Oidium stage of this species, in 1886, HARKNESS described it as follows: "*Oidium ventricosum;* segment swelling in the center and becoming barrel-shaped, 34–38 × 20–22 μ, and filled with numerous round or elliptic bodies, 5–6 × 2–4 μ, which are freely discharged from the end, as the joints separate". The writer examined the conidia in the Japanese materials and observed the same facts. The conidia of *Cystotheca lanestris* are easily distinguished from

those of the species of Sphaerotheca, and the special formed hairs are abundantly produced from the creeping mycelium. From these two characters together with the easily separable character of the outer and inner walls of the perithecium, the present fungus ought to be treated as a species belonging to the Cystotheca.

In the present species, the mycelial hyphae form a very dense mass, presenting a grayish brown color when mature. The hyphae are more slender than those of *Cystotheca Wrightii*. The fungus is always parasitic on the under surface of the leaves of deciduous Quercus, and is widely distributed in all parts of this country. The hairs are light brown in color, slender, flexuous, aseptate, thin-walled and equal to a mycelium in width, reaching 135 μ in length. The inner wall of the perithecium is composed of colorless and fine hexagonal cells which are more or less larger than those of the outer wall. The outer wall is dark brown in color and obscurely reticulate. The appendages are sparingly produced from the basal portion of the perithecium. They are hyaline or pale brown, interwoven with the mycelial hyphae, so that it is difficult to distinguish between them.

This species somewhat resembles *Sphaerotheca pannosa* and *Erysiphe graminis* at first sight, but *Sphaerotheca pannosa* never produces hair-like bodies from the superficial mycelium, the two layers of the perithecial wall are not separable, and *Erysiphe graminis* has many asci.

Sphaerotheca LÉV.

Mycelium persistent or evanescent; matured conidia are produced in a chain, subglobose, ellipsoidal or elongate-ellipsoidal, and include well-developed fibrosin bodies; perithecia globose, appendages simple or vaguely branched, brown or dark-brown colored, several septate; ascus 1; ascospores 6–8 in number.

In Japan six species are known so far in this genus.

This genus is distinguished from Erysiphe by its single ascus, and from Cystotheca by the lack of special hairs on the mycelium. Of *Sphaerotheca pannosa,* the perithecial stage has not yet been found in this country, in spite of careful search for several years, but there is no doubt that the powdery mildew of our rose plant belongs to the species judging from the characters of its Oidium and mycelium.

Key to the species of the genus Sphaerotheca

I. Mycelium becoming gray or pale brown colored when mature ..*S. pannosa* (311)
II. Mycelium becoming brown or deep-brown colored when mature.
  a. Cells of the outer wall of the perithecium small, 12.0—26.4×9.6—19.2μ.
    1. Diameter of the perithecia 70—112μ..................*S. Humuli* (296)
    2. Diameter of the perithecia 64.8—86.4μ................*S. Epilobii* (300)
  b. Cells of the outer wall of the perithecium irregular and always larger, 19.2—55.2×10.8—36.0μ ....*S. fuliginea* (301)
III. Mycelium becoming blackish-brown or black colored when mature.
    1. Diameter of the perithecia 94—126μ ....*S. Mors-Uvae* (309)
    2. Diameter of the perithecia 74—98μ...................*S. japonica* (310)

Sphaerotheca Humuli (DC.) BURR.

(Pl. VII, figs. 4, 5, 6, 7)

Bull. Ill. State Lab. Nat. Hist. II, p. 400, 1887; ELL. & EVERH. N. Amer. Pyren. p. 5, 1892; SALM. Monogr. Erysiph. p. 45, (p.p.), 1900, and Bull. Torr. Bot. Club, XXIX, p. 87 (p.p.), 1902; NEGER, Kryptg. Fl. d. Mark Brand. VII, p. 106 (p.p.), 1905; JØRST. Erysiph. Norway, p. 14 (p.p.), 1925; ŠKOLIĆ, Erysiph. Croat. p. 34, 1926; TAI & WEI, Sinensia, III, p. 97, 1932. (PAMM. Journ. Myc. IV, p. 36, 1888; TRACY & GALLOWAY, Journ. Myc. IV, p. 34, 1888; GRIFF. Bull. Torr. Bot. Club, XXVI, p. 143, 1899; SALM. Bull. Torr. Bot. Club, XXVII, p. 445 (p.p.), 1900, Ann. Myc. III, p. 252, 1905, and VI, p. 11, 1908; SHIRAI, List, p. 93, 1905; LAWRENCE, Journ. Myc. XI, p. 107, 1905; NAMBU, Bot. Mag. Tokyo, XX, p. 252, 1906; JAAP, Ann. Myc. IX, p. 333, 1911; IDETA, Japanese Phytopathology, p. 201, 1911, and Japanese Phytopathology (Suppl. I), p. 202, 1923; SYDOW, Ann. Myc. XI, p. 113, 1913; MIYAKE, Bot. Mag. Tokyo, XXVIII, p. 38, 1914; SAWADA, Agric. Experiment Station, Formosa Spec. Bull. IX, p. 42, 1914; SHIRAI & MIYAKE, List, p. 625 (p.p.), 1917; TOGASHI & HIRATSUKA, Transact. Sapporo Nat. Hist. Society, XVI, p. 74, 1924; SHIRAI & HARA, List, p. 375 (p.p.), 1927; MIURA, South Manch. Rwy. Co. Agr. Rep. XXVII, p. 115, 1928.)

Syn. *Erysiphe Humuli* DC. Fl. Fr. VI, p. 106, 1815.

Erysiphe Sanguisorbae DC. Fl. Fr. VI, p. 108, 1815.

Erysibe macularis SCHLECHT. Fl. Berol. II, p. 168, 1824; RABENH. Deutschl. Krypt. Fl. I, p. 231 (p.p.), 1844.

Erysiphe fuliginea FR. Syst. Myc. III, p. 238 (p.p.), 1829.

Erysiphe horridula RABENH. Deutschl. Krypt. Fl. I, p.235, (p.p.), 1844.

Sphaerotheca Castagnei LÉV. Ann. Sci. Nat. III, 15, p. 139 (p.p.), 1851; KICKX, Fl. Crypt. Fland. I, p. 375 (p.p.), 1867; COOKE, Handb. Brit. Fung. II, p. 645 (p.p.), 1871; COOKE & PECK, Journ. Bot. I, p. 11, 1872; QUÉL. Champ. Jur. Vosg. p. 533 (p.p.), 1875; SACC. Syll. Fung. I, p. 4 (p.p.), 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 27 (p.p.), 1884; ELL. & EVERH. N. Amer. Pyren. p. 8 (p.p.), 1892; JACZEW. Bull. l'Herb. Boiss. IV, p. 725 (p.p.), 1896; OUDEM. Rév. Champ. Pays-Bas, II, p. 83 (p.p), 1897; MAGNUS, Erysiph. Tirol. p. 6 (p.p.), 1898; KLIKA, Erysiph. Czechosl. p. 38 (p.p.), 1924. (FUCK. Symb. Myc. p. 78 (p.p.), 1869–70; GRIFF. Bull. Torr. Bot. Club, XXVI, p. 142 (p.p.), 1899; P. HENN. in Engl. Bot. Jahrb. XXVIII, p. 271, 1901; YOSHINAGA, Bot. Mag. Tokyo, XIX, p. 34, 1905).

Sphaerotheca Niesslii THÜM. Verh. k. k. zool.-bot. Gesell. Wien. XXIX, p. 524, 1880; SACC. Syll. Fung. I, p. 4, 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 28, 1884.

Sphaerotheca fugax PENZ. et SACC. Att. R. Instit. Ven. VI, 2, p. 10, 1884; SACC. Syll. Fung. Addit. ad. I–IV, p. 1, 1886, and IX, p. 365, 1891; MAGNUS, Erysiph. Tirol. p. 6, 1898.

Sphaerotheca Humuli (DC.) SCHRÖT. in Cohn's Krypt. Fl. Schles. III, p. 231 (p.p.), 1893. (RANOJEVIC, Ann. Myc. VIII, p. 355, 1910).

Oidium botryoides CES. in Kl. Herb. viv. Myc. no. 1671, Bot. Zeit. p. 302, 1852; SACC. Syll. Fung. XXII, p. 1250, 1913.

Oidium erysiphoides FR. Syst. Myc. III, p. 432 (p.p.), 1829; SACC. Syll. Fung. IV, p. 41 (p.p.), 1886; LIND. in RABENH. Krypt. Fl. Deutschl. VIII, p. 79 (p.p), 1907.

Amphigenous, also on stems, petioles and fruits, mycelium persistent or evanescent; matured conidia produced in a chain, vacuolate, including the well developed fibrosin bodies, 25.2–36.0 × 13.2–22.4 μ; perithecia gregarious or scattered, 70–112 μ in diameter, globose or depressed-globose; cells 12.0–26.4 × 9.6–19.2 μ in size; appendages 9–19 in number, irregular in length, about 168–448 μ, 1–4 septate, dark-brown colored throughout their length or light brown colored towards the apex, simple, very rarely branched; ascus 1, oblong, with or without stalk, 52.8–103.2 × 42.8–88.8 μ, (on Geranium, 91.2–120.0 × 50.8–76.8 μ); spores 6–8 in number, ellipsoidal or oblong, 16.8–26.4 × 10.4–19.2 μ.

Hab. On leaves and stems of *Corydalis ochotensis* TURCZ. (Tsuru-kikeman). Hokkaido—Ishikari. Honshu—Rikuchu.

On *Astilbe Thunbergii* MIQ. (Akashoma). Honshu—Etchu.

On *Astilbe Thunbergii* MIQ. var. *congesta* Boiss. (Toriashishoma). Honshu—Uzen, Echigo.

On *Agrimonia pilosa* LEDEB. (Yezo-Kinmizuhiki). Hokkaido—Oshima, Shiribeshi, Iburi, Ishikari, Kitami, Hidaka, Kushiro. Honshu—Rikuchu.

On *Aruncus silvester* KOSTEL. var. *americana* MAXIM. (Yamabuki-shoma). Hokkaido—Kurile Isls. Etorofu Isl., Shiribeshi, Ishikari, Tokachi, Kushiro. Honshu—Rikuchu, Echigo.

On *Aruncus silvester* KOSTEL, var. *vulgaris* MAXIM. (Yezo-Yamabuki-shoma). Saghalien—Odomari. Hokkaido—Ishikari.

On *Filipendula ciliata* KUDO (Akabana-shimotsuke). Hokkaido—Ishikari, Kushiro.

On *Filipendula kamtschatica* MAXIM. (Oni-shimotsuke). Saghalien—Airoppu, Shiraraka, Nayashi, Makunkotan, Nupuripo, Manue, Ochiai, Tominai, Chikahoro, Aba, Konuma, Kurokawa. Hokkaido—Kurile Isls. Shikotan Isl., Etorofu Isl., Shimushir Isl., Kunashiri Isl., Oshima, Iburi, Ishikari, Kitami, Tokachi, Kushiro. Honshu—Rikuchu.

On *Filipendula palmata* MAXIM. (Urajiro-shimotsuke). Saghalien—Gorojikoff.

On *Fragaria chiloensis* DUCH. var. *ananassa* BAILEY (Seiyo-Ichigo). Honshu—Musashi.

On *Fragaria negrecta* LINDEM. (Yezo-kusa-ichigo). Hokkaido—Tokachi.

On *Potentilla centigrana* MAXIM. (Hime-hebi-ichigo). Hokkaido—Ishikari.

On *Potentilla fragarioides* L. var. *Sprengeliana* MAXIM. (Kijimushiro). Hokkaido—Shiribeshi, Ishikari, Tokachi, Hidaka.

On *Potentilla Freyniana* BORNM. (Mitsuba-tsuchiguri). Hokkaido—Ishikari.

On *Sanguisorba canadensis* L. var. *media* MAXIM. (Usubeni-waremoko). Honshu—Iwaki.

On *Sanguisorba officinalis* L. (Waremoko). Hokkaido—Ishikari. Honshu—Mutsu, Rikuzen, Musashi, Shimotsuke. Shikoku—Tosa. Kyushu—Higo.

On *Sanguisorba officinalis* L. var. *carnea* REGEL (Yezo-waremoko). Hokkaido—Ishikari, Hidaka.

On *Sanguisorba tenuifolia* Fisch. var. *alba* TRAUTV. & MEY. (Nagabono-shirobana-waremoko). Saghalien—Odomari, Konuma, Ehorokofunai, Uenchishi, Ochiai, Alexandrowsk, Shisuka, Kitanayoshi, Abe. Hokkaido—Kurile Isls. Etorofu Isl., Shiribeshi, Iburi, Ishikari, Kitami, Tokachi, Kushiro. Honshu—Mutsu, Rikuchu.

On *Spiraea prunifolia* S. & Z. var. *plena* SCHNEID. (Shijimibana). Honshu—Rikuchu.

On *Spiraea Thunbergii* SIEB. (Yukiyanagi). Honshu—Mutsu, Rikuchu.

On *Geranium erianthum* DC. (Chishimafuro). Hokkaido—Kitami, Tokachi.

On *Geranium nepalense* SWEET. var. *Thunbergii* KUDO (Gennoshoko). Hokkaido—Oshima, Shiribeshi, Ishikari. Honshu—Echizen, Shinano.

On *Geranium sibiricum* L. (Ichige-furo). Hokkaido—Ishikari, Kitami.

On *Geranium yezoense* FR. & SAV. (Yezo-furo). Hokkaido—Kurile Isls. Etorofu Isl., Kunashiri Isl., Ishikari.

On *Geranium yezoense* FR. & SAV. var. *nipponicum* NAKAI (Hakusan-furo). Honshu—Shinano.

On *Polemonium coeruleum* L. var. *laxiflorum* MIYABE & MIYAKE (Karafuto-hanashinobu). Saghalien—Ambetsu.

On *Clerodendron trichotomum* THUNB. (Kusagi). Hokkaido—Ishikari. Honshu—Bichu.

On *Veronica Grayi* MIYABE & KUDO (Yezo-ruri-toranoo) . Saghalien—Ambetsu.

On *Veronica sibirica* L. (Yezo-kukaiso). Hokkaido—Ishikari.

On *Veronica virginica* L. var. *japonica* NAKAI (Kukaiso). Honshu—Hoki.

On *Melothria japonica* MAXIM. (Suzumeuri). Honshu—Echigo, Etchu.

On *Lactuca Scariola* L. var. *integrata* GRENIER & GODRON. (Ryuzetsuna). Honshu—Etchu.

Distrib. Japan (Saghalien, Hokkaido including Kurile Islands, Honshu, Shikoku, Kyushu and Formosa), Manchuria, China, Europe, North America and South Africa.

Remarks. This species which is well-known as hop-mildew in Europe and America, where it causes great damage to the cultivated hop, has not yet been found on either wild or cultivated hop-plant in this country. This remarkable fact can only be explained by the absence in this country of the specialized form which attacks the species of Humulus. The present species is however, most common and destructive on the following host plants; Corydalis, Astilbe, Agrimonia, Aruncus, Filipendula, Fragaria, Potentilla, Sanguisorba, Spiraea, Geranium, Veronica, Polemonium, Clerodendron, Melothria and Lactuca.

Compared with *Sphaerotheca fuliginea*, the outer wall cells of the perithecium of this fungus are smaller in size and, besides, the conidia of this species are not produced as abundantly as in *Sphaerotheca fuliginea*.

The form on *Aruncus silvester* var. *vulgaris* has remarkably well-developed fibrosin bodies in the ascospores.

The form on *Geranium nepalense* var. *Thunbergii* (Zenibako, Nov. 1, 1925, Y. HOMMA), has a very large-sized ascus, 91.2–120.0 × 50.4–76.8 μ; besides, this fungus causes hyperplasy on the upper part of the stem. The author at first thought it to be a new species, but from the examination of many specimens which were collected in different parts of this country, she has come to the conclusion that it is better to consider it as a special abnormal form of the species.

In the form on *Spiraea Thunbergii*, the appendages are frequently branched in the lower half and the perithecia are smaller, being 52.8–55.2 × 42.4–48.0 μ.

The form on *Veronica sibirica*, (Mt. Moiwa, Oct. 6, 1924, H. TAKASUGI), is very interesting, as it frequently includes two asci in a perithecium, one of which is smaller than the other when mature. The size of the asci when single in a perithecium is 72.0–81.6 × 52.6–62.4 μ and when there are two it is 52.8–75.6 × 43.2–58.8 μ. A careful examination of the specimens of this fungus on the present host gathered in different places in the vicinity of Sapporo and also the specimens on *Veronica virginica* in the American Exsiccatae, has failed, however, to reveal such an occurrence. This character may be abnormal, but it is interesting as it shows an intermediate character between Sphaerotheca and Erysiphe.

Sphaerotheca Epilobii (WALLR.) SACC.

(Pl. VII, figs. 8, 9)

Syll. Fung. I, p. 4, 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 27, 1887; ELL. & EVERH. N. Amer. Pyren. p. 8, 1892; SCHRÖT. in Cohn's Krypt. Fl. Schles. III, p. 232, 1893; MAGNUS, Erysiph. Tirol. p. 9, 1898. (GRIFF. Bull. Torr. Bot. Club, XXVI, p. 143, 1899; RANOJEVIC, Ann. Myc. VIII, p. 356, 1910).

Syn. *Alphitomorpha Epilobii* WALLR. Ann. Wett. Ges. IV, p. 243, 1819.

Erysiphe Epilobii LK. in WILLD. Sp. Pl. VI, p. 102, 1824.

Erysiphe macularis SCHLECHT. Fl. Berol. II, p. 168, 1824; RABENH. Deutschl. Krypt. Fl. I, p. 231 (p.p.), 1844.

Podosphaera Epilobii DE BARY, Beitr. Morph. Phys. Pilze, I, xiii, p. 48, 1870, and Hedw. X, p. 68, 1871.

Sphaerotheca Humuli BURR. in SALM. Monogr. Erysiph. p. 45 (p.p.), 1900, and Bull. Torr. Bot. Club, XXIX, p. 87 (p.p.), 1902; NEGER, Krypt. Fl. d. Mark Brand. VII, p. 106 (p.p.), 1905; JØRST. Erysiph. Norway, p. 14 (p.p.), 1925. (SALM. Bull. Torr. Bot. Club, XXVII, p. 445 (p.p.), 1900; SHIRAI & MIYAKE, List, p. 625 (p.p.), 1917; SHIRAI & HARA, List, p. 370 (p.p.), 1927).

Sphaerotheca Castagnei LÉV. Ann. Sci. Nat. III, 15, p. 139 (p.p.), 1851; KLIKA, Erysiph. Czechosl. p. 38 (p.p.), 1924. (FUCK. Symb. Myc. p. 79 (p.p.), 1869–70).

Torula Epilobii CORDA, Icon. Fung. IV, p. 23, 1840.

Oospora Epilobii (CORDA) SACC. et VOGL. Syll. Fung. IV, p. 12, 1886.

Oidium Epilobii (CORDA) LIND. in RABENH. Krypt. Fl. Deutschl. VIII, p. 81, 1907, and IX, p. 726, 1910.

Amphigenous, also on stems and fruits, mycelium persistent, densely white powdery at first, finally turning to blackish brown; matured conidia borne in a chain, vacuolate, granulate, including the well-developed fibrosin bodies, ellipsoidal in shape, 25.2–30.0 × 13.2–16.8 μ; perithecia gregarious, small, 64.8–86.4 μ in diameter; cells 15.6–26.4 × 12.0–14.4 μ in size; appendages 9–15 in number, deep brown colored throughout their length or hyaline at the upper part, simple, 2–3 septate, about 126–294 μ long and 7.2μ wide at the base and the apical part 3.2 μ; asci small, ellipsoidal, without stalk, thick-walled, 55.2–86.4 × 33.6–56.4 μ; spores 7–8 in number, usually 8, oblong or ellipsoidal, 14.4–19.2 × 9.6–10.8 μ in size.

Hab. On leaves and stems of *Epilobium Behringianum* HAUSSKU. (Tarao-akabana). Saghalien—Mt. Shiretori. Hokkaido—Kurile Isls. Shimushir Isl., Iburi, Tokachi.

On *Epilobium cephalostigma* HAUSSKU. (Iwa-akabana). Saghalien—Mt. Suzuya, Konuma. Hokkaido—Shiribeshi, Ishikari.

On *Epilobium glandulosum* LEHM. (Karafuto-akabana). Saghalien—Ushoro, Obedomari, Manue, Alexandrowsk, Kita-nayoshi, Konuma. Hokkaido—Kurile Isls. Etorofu Isl., Shiribeshi, Ishikari, Kushiro.

On *Epilobium montanum* L. (Yezo-akabana). Hokkaido—Iburi, Ishikari.

On *Epilobium palustre* L. (Yanagi-akabana). Saghalien—Tominai.

On *Epilobium pyrricholophum* FR. & SAV. (Akabana). Kyushu— Bungo.

Distrib. Japan (Saghalien, Hokkaido including Kurile Islands, Honshu and Kyushu), Europe and North America.

Remarks. This species is readily distinguished from *Sphaerotheca Humuli* by the smaller size of the perithecia. In 1900, SALMON (32) stated that "*Erysiphe Epilobii* is identical with certain forms of *S. Humuli*. No sufficient distinguishing characters have been given in any diagnosis of this form, and it is evident that, as a general rule, specimens have been referred to '*S. Epilobii*' merely from their occurrence on species of *Epilobium*". But, in this fungus, the size of the perithecia, asci and ascospores is less than the measurements of those of *S. Humuli*, and the appendages become narrow at the apical portion. Compared with *S. fuliginea* the wall cells of the perithecium in the present species are smaller in size.

Sphaerotheca fuliginea (SCHLECHT.) POLLACCI

(Pl. VII, figs 10, 11, 12, 13, 14, 15)

R. Ist. Bot. Univ. Pavia, p. 8, 1905; SACC. Syll. Fung. XXII, p. 20, 1913; KLIKA, Erysiph. Czechosl. p. 39, 1924; ŠKORIĆ, Erysiph. Croat. p. 35, 1926.

Syn. *Alphytomorpha fuliginea* SCHLECHT. Berl. Ges. Nat. Freund. Verh. I, p. 47, 1819.

Erysiphe fuliginea (WALLR.) FR. Syst. Myc. III, p. 238 (p.p.), 1829.

Erysiphe communis FR. Syst. Myc. III, p. 239 (p.p.), 1829; MAGNUS, 'Erysiph. Tirol. p. 15 (p.p.), 1898.

Erysiphe fusca FR. Syst. Myc. III, p. 242, 1829.

Erysibe lamprocarpa RABENH. Deutschl. Krypt. Fl. I, p. 232 (p.p.), 1844.

Erysibe communis RABENH. Deutschl. Krypt. Fl. I, p. 232 (p.p.), 1844.

Erysibe circumfusa RABENH. Deutschl. Krypt. Fl. I, p. 232 (p.p.), 1844.

Sphaerotheca Castagnei LÉV. Ann. Sci. Nat. III, 15, p. 139 (p.p.), 1851; KICKX, Fl. Crypt. Fland. I, p. 375 (p.p.), 1867; COOKE, Handb. Brit. Fung. II, p. 645 (p.p.), 1871; SACC. Syll. Fung. I, p. 4 (p.p.), 1882; BURR. & EARLE, Bull. Ill. Stat. Lab. Nat. Hist. II, p. 400, 1887; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 27 (p.p.), 1884; ELL. & EVERH. N. Amer. Pyren. p. 8 (p.p.), 1892; JACZEW. Bull. l'Herb. Boiss. IV, p. 725 (p.p.), 1896; OUDEM. Rév. Champ. Pays-Bas, II, p. 83 (p.p.), 1897; MAGNUS, Erysiph. Tirol. p. 6 (p.p.), 1898. (FUCK. Symb. Myc. p. 79 (p.p.), 1869–70; PAMM. Journ. Myc. IV, p. 36, 1888; GALLOW. Journ. Myc. IV, p. 33, 1888; GRIFF. Bull. Torr. Bot. Club, XXVI, p. 142 (p.p.), 1899; RANOJ. Hedw. XLI, p. 102, 1902; SHIRAI, List, p. 93, 1905; P. HENN. in ENGL. Bot. Jahrb. XXXIV, p. 600, 1905; SHIRAI & MIYAKE, List, p. 625, 1917).

Sphaerotheca detonsa KICKX, Fl. Crypt. Fland. I, p. 375, 1867; SACC. Syll. Fung. I, p. 4, 1882.

Podosphaera Castagnei (LÉV.) DE BARY, Beitr. Morph. Phys. Pilz. I, xiii, p. 48, 1870.

Sphaerotheca Drabae JUEL, Bot. Notis. p. 9, 1890; SACC. Syll. Fung. IX, p. 365, 1891.

Sphaerotheca Calendulae (MALBR. & ROUM.) MALBR. & ROUM. Bull. Soc. Myc. France, IV, p. xxxii, 1888; SACC. Syll. Fung. IX, p. 366, 1891.

Sphaerotheca Humuli (DC.) SCHRÖT. in COHN's Krypt. Fl. Schles. III, p. 231 (p.p.), 1893. (P. HENN. in ENGL. Bot. Jahrb. XXIX, p. 148, 1901).

Sphaerotheca Humuli (DC.) BURR. var. *fuliginea* (SCHLECHT.) SALM. Monogr. Erysiph. p. 49, 1900, and Bull. Torr. Bot. Club, XXIX,

p. 89, 1902; LAWRENCE, Journ. Myc. XI, p. 107, 1905; TAI & WEI, Sinensia, III, p. 98, 1932. (MATSUM. Ind. Plant. Jap. I, p. 174, 1904; SHIRAI, List, p. 94, 1905; SALM. Bull. Torr. Bot. Club. XXVII, p. 446, 1900, Ann. Myc. III, p. 252, 1905, and VI, p. 11, 1908; MIYAKE, Bot. Mag. Tokyo, XXVI, p. 53, 1912, XXVII, p. 38, 1913, and XXVIII, p. 38, 1914; SYD. Ann. Myc. XI, p. 113, 1913; DOIDGE, Roy. Soc. South Afr. V, p. 239, 1915; SHIRAI & MIYAKE, List, p. 627, 1917).

Sphaerotheca fuliginea (FR.) LIND, Danish Fung. p. 160, 1913.

Sphaerotheca fuliginea (SCHLECHT.) SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 37, 1914; HARA, Shizuoka, Agr. Rep. CCCLXIV, p. 4, 1928. (SAWADA, Agr. Exp. Stat. Formosa, Bull. XIX, p. 150, 1919; IDETA, Jap. Phytopath. (Suppl. I), p. 203; 1923; TOGASHI, Jap. Journ. Bot. II, p. 78, 1924; SHIRAI & HARA, List, p. 370, 1927; MIURA, South Manch. Rwy. Co. Agr. Rep. XXVII, p. 116, 1928).

Sphaerotheca Phteirospermi P. HENN. et SHIRAI, in ENGL. Bot. Jahrb. XXIX, p. 147, 1901; SACC. Syll. Fung. XVI, p. 402, 1902. (SHIRAI, List, p. 94, 1905; SHIRAI & MIYAKE, List, p. 629, 1917).

Sphaerotheca fuliginea (SCHLECHT.) LIND, (emend JØRST.), in JØRST. Erysiph. Norway, p. 27, 1925.

Oidium erysiphoides FR. Syst. Myc. III, p. 432 (p.p.), 1829; SACC. Syll. Fung. VI, p. 41 (p.p.), 1888; LIND. in RABENH. Krypt. Fl. Deutschl. VIII, p. 79 (p.p.), 1907.

Amphigenous, on petioles and stems, mycelium persistent or evanescent, forming white patches at first; matured conidia produced in a chain, subglobose, ellipsoidal or elongate-ellipsoidal, including the well-developed fibrosin bodies, 25.2–44.4 × 13.2–22.4 μ in size; perithecia gregarious or scattered, dark brown colored when mature, globose or depressed globose, 70.0–112.0 μ in diameter; cells evident, large size, 19.2–55.2 × 10.8–36.0 μ; appendages variable in number and length, 5–21 in number, rarely 2, some shorter than diameter of the perithecia, while some 8 times longer, brown colored throughout or hyaline in the upper half or gradually becoming a light color, mostly simple, rarely 1 or 2 branched, aseptate or 1–5 septate; asci hyaline, broadly ovate or subglobose, without stalk, 57.6–100.8 × 40.0–81.6 μ; spores 5–8 in number, usually 8, subglobose, broadly oblong or ellipsoidal, 14.4–25.2 × 10.8–18.0 μ.

Hab. On leaves and stems of *Fatoua pilosa* GAUD. var. *subcordata* BUREAU. (Kuwakusa). Honshu—Musashi. Shikoku—Tosa. Kyushu—Hizen, Higo.

On *Saxifraga fusca* MAXIM. (Kurokumoso). Hokkaido—Ishikari.

On *Saxifraga reflexa* HOOK. f. (Yamahanaso). Hokkaido—Ishikari.

On *Phaseolus radiatus* L. var. *aurea* PRAIN (Azuki). Honshu—Etchu, Echizen, Kaga.

On *Acalypha australis* L. (Enoki-gusa). Hokkaido—Ishikari. Honshu—Etchu.

On *Impatiens Balsamina* L. (Hosenkwa). Honshu—Musashi, Echigo, Etchu. Shikoku—Tosa. Kyushu—Higo, Osumi.

On *Impatiens Noli-tangere* L. (Ki-tsurifune). Saghalien—Odomari, Akashiki, Chikahoro. Hokkaido—Shiribeshi, Ishikari, Kitami, Tokachi, Kushiro, Honshu—Echigo.

On *Impatiens Textori* MIQ. (Tsurifune). Hokkaido—Ishikari. Honshu—Musashi, Shimozuke.

On *Halorrhagis micrantha* R. BR. (Arinotogusa). Hokkaido—Ishikari. Honshu—Etchu.

On *Cynanchum yezoense* NAKAI (Oh-kamomezuru). Honshu—Echigo.

On *Cynanthum caudatum* MAXIM. (Ikema). Honshu—Etchu.

On *Ajuga ciliata* BUNGE (Kaijindo). Hokkaido—Ishikari.

On *Ajuga yezoensis* MAXIM. (Nishikigoromo). Hokkaido—Ishikari.

On *Clinopodium chinensis* KUNTZE (Kurumabana). Hokkaido—Ishikari.

On *Clinopodium chinensis* KUNTZE var. *macrantha* MAKINO (Miyama-tohana). Hokkaido—Ishikari.

On *Nepeta Glechoma* BENTH. (Kakidoshi). Honshu—Yamashiro.

On *Nepeta subsessilis* MAXIM. (Misogawaso). Hokkaido—Kushiro.

On *Euphrasia Maximowiczii* WETTST. (Tachi-kogomegusa). Saghalien—Toyohara.

On *Lagotis glauca* GAERTH. (Uruppuso). Hokkaido—Kurile Isls. Shimushir Isl.

On *Pedicularis euphrasioides* STEPH. (Chishima-shiogama). Hokkaido—Kurile Isls. Ketoi Isl.

On *Pedicularis japonica* MIQ. var. *Maximowiczii* NAKAI (Yezono-yotsuba-shiogama). Hokkaido—Kurile Isls. Ushishiru Isl.

On *Pedicularis resupinata* L. (Shiogama-giku). Saghalien—Kitanayoshi, Tominai.

On *Phteirospermum japonicum* KANITZ. (Ko-shiogama). Hokkaido—Oshima. Honshu—Rikuchu, Musashi. Shikoku—Tosa.

On *Dicliptera japonica* MAKINO (Haguroso). Honshu—Musashi, Echizen.

On *Benincasa hispida* COGN. (Toga). Honshu—Echigo.

On *Cucumis Melo* L. (Makuwa-uri). Hokkaido—Ishikari. Honshu—Musashi. Kyushu—Higo.

On *Cucumis sativus* L. (Kiuri). Hokkaido—Ishikari. Honshu—Musashi, Etchu.

On *Cucurbita moschata* DUCH. var. *Toonas* MAKINO (Tonasu). Hokkaido—Ishikari. Honshu—Musashi, Yamashiro.

On *Cucurbita moschata* DUCH. var. *melonaeformis* MAKINO (Kikuza-tonasu). Honshu—Echigo. Kyushu—Hizen, Higo.

On *Lagenaria vulgaris* SER. (Hyotan). Hokkaido—Ishikari. Kyushu—Hizen.

On *Adenocaulon bicolor* HOOK. var. *adhaerescens* MAKINO (Nobuki). Hokkaido—Iburi, Ishikari, Hidaka, Kushiro. Honshu—Rikuchu.

On *Arctium Lappa* L. (Gobo). Hokkaido—Iburi, Ishikari. Honshu—Rikuchu, Musashi, Echigo, Etchu. Shikoku—Tosa. Kyushu—Higo.

On *Arnica sachalinensis* A. GR. (Oh-usagigiku). Saghalien—Makunkotan.

On *Aster pinnatifidus* MAKINO (Yugagiku). Honshu—Rikuchu, Kaga.

On *Aster tataricus* L. f. (Shion). Honshu—Etchu.

On *Bidens bipinnata* L. (Sendangusa). Honshu—Musashi. Shikoku—Tosa.

On *Bidens pilosa* L. (Ko-sendangiku). Honshu—Musashi.

On *Bidens pilosa* L. var. *albiflora* MAXIM. (Shiro-sendangusa). Shikoku—Tosa.

On *Bidens radiata* THUILL. (Yezo-no-taukogi). Hokkaido—Kushiro.

On *Bidens tripartita* L. (Taukogi). Honshu—Echigo.

On *Cacalia auriculata* DC. var. ochotensis KOM. (Karafuto-mimikomori). Saghalien—Shiretori, Chikahoro. Hokkaido—Kitami.

On *Cacalia auriculata* DC. var. *kamtschatica* KOIDZ. (Mimikomori). Saghalien—Konuma. Hokkaido—Tokachi.

On *Cacalia hastata* L. var. *glabra* LEDEB. (Yobusumaso). Saghalien—Odomari. Hokkaido—Ishikari, Kushiro.

On *Cacalia hastata* L. var. *pubescens* LEDEB. (Oh-yobusumaso). Saghalien—Makunkotan, Alexandrowsk, Ambetsu.

On *Carpesium abrotanoides* L. var. *Thunbergianum* MAKINO (Yabutabako). Hokkaido—Ishikari.

On *Carpesium triste* MAXIM. (Gankubi-yabutabako). Hokkaido—Shiribeshi, Ishikari.

On *Cirsium arvense* Scop. var. *setosum* LEDEB. (Yezo-no-kitsune-azami). Hokkaido—Ishikari.

On *Cirsium Buergeri* MIQ. var. *Albrechtii* NAKAI (Yezo-yama-azami). Hokkaido—Kitami.

On *Cirsium Grayanum* NAKAI (Maruba-no-hire-azami). Hokkaido—Ishikari, Kushiro.

On *Cirsium pendulum* FISCH. (Taka-azami). Hokkaido—Kushiro.

On *Cirsium Weyrichii* MAXIM. (Yezo-azami). Saghalien—Chikahoro. Hokkaido—Ishikari.

On *Cosmos bipinnatus* CAV. (Kosumosu). Honshu—Etchu.

On *Dahlia variabilis* DESF. (Daria). Honshu—Etchu.

On *Erigeron acre* L. var. *hirsutum* FR. SCHM. (Yezo-mukashiyomogi). Honshu—Mino.

On *Erigeron canadensis* L. (Hime-mukashiyomogi). Hokkaido—Ishikari. Honshu—Musashi, Echigo, Etchu.

On *Eupatorium Fortunei* TURCZ. var. *simplicifolium* NAKAI (Hiyodoribana). Honshu—Echigo.

On *Gerbera Anandria* SCH. BIP. (Sembonyari). Hokkaido—Ishikari. Honshu—Etchu.

On *Helianthus annuus* L. (Himawari). Hokkaido—Ishikari. Honshu—Musashi.

On *Helianthus tuberosus* L. (Kikuimo). Honshu—Etchu.

On *Lactuca dentata* MAKINO var. *Thunbergii* MAKINO (Nigana). Honshu—Musashi.

On *Lactuca denticulata* MAX. var. *typica* MAXIM. (Yakushiso). Hokkaido—Ishikari.

On *Lactuca laciniata* MAKINO (Aki-no-nogeshi). Honshu—Rikuchu, Musashi, Echigo, Etchu, Echizen, Kaga.

On *Lactuca laciniata* MAKINO f. *indivisa* MAKINO (Hosobano-aki-no-nogeshi). Hokkaido—Ishikari.

On *Lactuca Raddeana* MAXIM. (Yama-nigana). Hokkaido—Ishikari, Kushiro. Honshu—Rikuchu, Rikuzen, Izu, Yamashiro.

On *Lactuca sibirica* BENTH. (Yezo-murasaki-nigana). Saghalien—Oioro, Konuma.

On *Ligularia sibirica* CASS. var. *speciosa* DC. (Oh-otakarako). Saghalien—Nayoshi, Makunkotan, Kami-Arumudan.

On *Petasites japonica* MIQ. (Fuki). Honshu—Echigo.

On *Saussurea manshurica* KOM. (Yanone-azami). Saghalien—Akashiki, Ambetsu.

On *Senecio Cineraria* DC. (Shirotai-giku). Hokkaido—Ishikari.

On *Senecio nemorensis* L. var. *Fuchsii* KOCH. (Hosoba-kion). Saghalien—Ambetsu.

On *Siegesbeckia pubescens* L. (Menamomi). Hokkaido—Ishikari. Honshu—Rikuzen, Musashi, Echigo, Etchu, Kaga. Shikoku—Tosa. Kyushu—Higo.

On *Sonchus oleraceus* L. (Nogeshi). Hokkaido—Ishikari. Honshu—Echizen.

On *Taraxacum ceratophorum* DC. (Yezo-tampopo). Hokkaido—Ishikari, Tokachi.

On *Taraxacum officinale* WEB. (Tampopo). Honshu—Musashi. Shikoku—Iyo.

Distrib. Japan (Saghalien, Hokkaido including the Kurile Islands, Honshu, Shikoku, Kyushu and Formosa), Manchuria, China, Europe, South Africa and North America.

Remarks. This species is a very common powdery mildew parasitic on numerous annual and perennial herbs in this country. The mycelial hyphae on these host plants present a snowy white appearance during summer, when conidia are abundantly formed, but when the perithecia begin to be produced in autumn, they turn from pale brown to dark brown in color. It has such a wide range in host plants, that naturally there is more or less variation in the size and number of both ascigenous and conidial stages.

Sphaerotheca fuliginea can easily be distinguished from *S. Humuli* by the larger size of the outer wall cells of the perithecium. As to the mildew on *Cucurbitaceae*, in 1900, SALMON (32) said,

"although so many authors have referred the fungus on *Cucurbita* and *Cucumis* to '*S. Castagnei*', it seems very probable that a mistake has been made in the identification and that the fungus in question is an *Erysiphe*. In the first place, although one finds in herbaria very numerous examples of a fungus in the conidial (*Oidium*) stage on leaves of *Cucurbita* and *Cucumis* referred to *S. Castagnei*, in my experience no specimens in the perithecial stage are to be found in herbaria on these hosts. It is evident, therefore, that for some reason it has been the practice among mycologists to name any *Oidium* on *Cucurbita* and *Cucumis*, *S. Castagnei* LÉV. There can be no doubt also that this fungus on cucurbitaceous plants is extremely slow in producing perithecia, and the only example I have seen in this condition was gathered in the late summer at Reigate, England, in 1898. This as already mentioned, proved to be *Erysiphe Cichoracearum*"...."Further, not only are wrong host-plants for a certain species thus given, but as a natural consequence our knowledge of the geographical distribution of the species in question becomes erroneous. For instance, 'WINTER records the occurrence of '*Sphaerotheca Castagnei*' in foliis *Cucurbitacearum*' from the island of St. Thomas, Africa, an occurrence extremely interesting not only geographically but also climatically, as the island is on the equator. In the present confusion it is impossible to say whether the fungus was really '*S. Castagnei*' in a perithecial stage, or whether, as is more probable it was not merely an Oidium which had been referred to *S. Castagnei* in accordance with the usual custom". We have collected many specimens on Cucurbita and Cucumis too; almost all of them were in the conidial stage (Oidium), and the only one specimen on *Cucurbita moschata* var. *Toonas* which was collected by Prof S. ITO (Kotoni Prov. Ishikari, Sept. 17, 1925) had numerous fine perithecia. The character of this fungus is as follows: amphigenous, mycelium persistent; perithecia gregarious, subglobose, 84–98 μ in diameter; cells 27.2–31.2 × 15.6–16.8 μ wide; appendages about 9 in number, flexuous, deep brown colored from middle downward, 2 or 3 septate reaching 182 μ in length; ascus 1, subglobose, 64.8–70.8 × 55.2–57.6 μ spores 6–8 in number, oblong or ellipsoidal, 16.3–21.0 × 10.8–13.6 μ These characters show that the fungus is *Sphaerotheca fuliginea*.

The matured conidia on Cucurbita and Cucumis are produced in a chain, ellipsoidal or elongate ellipsoidal, vacuolate, including well developed fibrosin bodies, 31.2–33.6 × 19.2–21.6 μ. The presence of

the well-developed fibrosin bodies in the conidial cells is an important character in the genus Sphaerotheca; while in the genus Erysiphe, the fibrosin bodies are in the form of granules. As far as the specimens collected in this country are concerned, they are all referable to *S. fuliginea* and none to *Erysiphe Cichoracearum.*

The fungus on *Taraxacum ceratophorum,* is smaller than others in both conidial and perithecial stages; conidia are 25.2–28.8 × 13.2–15.2 μ in size; perithecia 70–84 μ in diameter; asci 57.6–66.0 × 40.0–48.0 μ; spores 16.8–18.0 × 10.8–12.0 μ in size; but the cells of the outer wall of the perithecium have form and size similar to those of others. It appeared to the writer at first to be a new species from the minute size of conidia and perithecia, but, according to SALMON in the specific range of the species, the forms having far smaller perithecia (50 μ) are included.

The fungus on *Phteirospermum japonicum,* P. HENNINGS (77) in 1902 described as *Sphaerotheca Phteirospermi* n. sp. (Mt. Takao, Prov. Musashi, Oct. 8, 1899, S. KUSANO). According to his description, the perithecia are 60–70 μ in diameter; asci 50–65 × 45–55 μ; spores 6–8 in number, 15–18 × 12–14 μ in size. The measurement of the co-type specimen, which was kindly given to us by Prof. Kusano, showed that the perithecia are 70–91 μ in diameter, the cells of the outer wall 24.0–31.2 × 14.4–28.8 μ wide; the asci 69.6–86.4 × 51.6–67.2 μ; the spores 19.2–20.8 × 14.4–16.8 μ. The writer found that in size the perithecia and asci respectively are larger than the original description. On the other hand, examination of the specimens collected in different localities on the same host resulted as follows: perithecia are 74.4–91 μ in diameter; cells 19.2–33.6 × 16.8–19.2 μ; asci 69.6–87.6 × 52.8–60.0 μ; spores 16.0–19.2 × 12.8–14.4 μ. From these comparative studies, this fungus seems to be a normal *S. fuliginea.*

On *Bidens pilosa, Clerodendron trichotomum* and *Siegesbeckia orientalis,* the appendages are frequently branched at the base or at about midway of their length. *Acalypha australis, Dicliptera japonica, Halorrhagis micrantha, Petasites japonica, Cosmos bipinnatus, Dahlia variabilis, Aster pinnatifidus,* and *Helianthus annus* are new hosts to this species.

Sphaerotheca Mors-Uvae (SCHWEIN.) BERK. & CURT.

(Pl. VII, fig. 16)

Grevillea, IV, p. 158, 1876; SACC. Syll. Fung. I, p. 5, 1882; BURR. & EARLE, Bull. Ill. Stat. Lab. Nat. Hist. II, p. 399, 1887; ELL. & EVERH. N. Amer. Pyren. p. 7, 1892; SALM. Monogr. Erysiph. p. 70, 1900, Bull. Torr. Bot. Club, XXIX, p. 93, 1902; NEGER, Krypt. d. Mark Brand. VII, p. 107, 1905; LIND, Danish Fung. p. 160, 1913; JØRST. Erysiph. Norway, p. 36, 1925; ŠKORIĆ, Erysiph. Croat, p. 36, 1926; HOMMA, Engei, XIX, p. 5, 1927. (GALLOW. Journ. Myc. IV, p. 34, 1888; GRIFF. Bull. Torr. Bot. Club, XXVI, p. 143, 1899; LAWR. Journ. Myc. XI, p. 107, 1905; REHM, Ann. Myc. XII, p. 170, 1914).

Syn. *Erysiphe Mors-Uvae* SCHWEIN. Syn. Fung. Am. Bor. p. 270, 1834.

Sphaerotheca Mors-Uvae (SCHWEIN.) BERK. & CURT. f. *Grossulariae* KLIKA, Erysiph. Czechosl. p. 42, 1924.

Amphigenous, mostly hypophyllous, on young shoots and surface of the fruits; mycelium persistent, white at first, turning to blackish brown when the perithecia are formed; matured conidia borne in a chain, vacuolate, including the well-developed fibrosin bodies, subglobose or ellipsoidal, 25.2–28.8 × 16.8–20.0 μ; perithecia gregarious, 94–126 μ in diameter, globose or subglobose; cells 14.4–21.6 × 10.8–16.8 μ in size; appendages 3–4 in number, simple or irregularly branched at the apex, several-septate, brown colored throughout, 33.6–74.4 μ in length; ascus 1, elongate-ellipsoidal, very short stalked, 81.6–100.8 × 50.4–69.6 μ; spores are always 8 in number, elongate-ellipsoidal or elongate-oblong, 20.4–25.2 × 9.6–12.0 μ.

Hab. On leaves, stems and fruits of *Ribes Grossularia* L. (Maru-suguri). Hokkaido—Ishikari, Kitami, Tokachi.

Distrib. Japan (Hokkaido), Manchuria, Europe and North America.

Remarks. This species which is known as the American-Gooseberry mildew is now distributed on the wild and cultivated gooseberry in almost every country where it is grown, causing great injury to the plant.

In 1834, SCHWEINITZ gave the name *Erysiphe Mors-Uvae* to this species on wild Ribes, endigenous in the United States. In 1900, it

was reported from Ireland by MASSEE and BRENAN. In 1902, P. HENNINGS reported it from Russia. In 1904, it reached Denmark. In 1905, it was reported from Sweden by Eriksson; at about the same time the fungus appeared in Norway, Italy (reported by POLLACCI) and Germany (noted by ADERHOLD). In 1906, SALMON reported its occurrence in several places in England, and FREEMAN and KÖCK reported it from Austria. In 1908, LEMCKE reported it from Czechoslovakia. In France the fungus may have been present from the year 1906, but the report of its occurrence was not heard until 1913. In 1914, it was reported to occur in Manchuria, where the fungus seems to have been present since 1912. On June 1927, our attention was first drawn to its occurrence in the vicinity of Sapporo where it presented already the appearance of an epidemic. Since then the fungus has spread in several districts of Hokkaido causing great damage.

This species occurs on the fruits, leaves and apical parts of new shoots. Small white patches are produced at first on them and then the patches are covered with a white powder. Finally the mycelium becomes blackish brown in color, when the perithecia are abundantly produced on it. The conidia are very similar in form to those of *Sphaerotheca pannosa*, but more or less larger; also, in *S. pannosa* the mycelium never changes to blackish brown when mature, but becomes brownish gray in color.

Sphaerotheca japonica (SALM.) HOMMA, comb. nov.

(Pl. VII, fig. 17)

Syn. *Sphaerotheca Mors-Uvae* (SCHWEIN.) BERK. & CURT. var. *japonica* SALM. Ann. Myc. VI, p. 2, 1908; SACC. Syll. Fung. XXII, p. 19, 1913; (SALM. Ann. Myc. VI, p. 11, 1908; SHIRAI & MIYAKE, List, p. 629, 1917; HARA, Dendropath. p. 6, 1923; SHIRAI & HARA, List, p. 371, 1927).

Hypophyllous, mostly on upper part of the new branches; mycelium persistent, densely pannose, yellowish-brown or dark brown colored, septate, branched; perithecia gregarious, more or less imbedded in the mycelial hyphae, globose or depressed-globose, 74–98 μ in diameter; appendages 6–9 in number, irregular in length, shorter than diameter of perithecia or reaching to 304 μ; dark brown throughout when mature, 2 or 3 septate, very rarely irregularly branched;

ascus 1, subglobose, thick walled, 44.8–52.8 × 36.0–38.4 μ; spores immature.

Hab. On leaves and stems of *Stephanandra incisa* ZABEL. (Kogome-utsugi). Honshu—Rikuchu.

Distrib. Japan (Honshu).

Remarks. The mycelium of this fungus is blackish-brown colored, forming a dense mycelial mass on the apical part of the branches. Frequently it occurs on the under-surface of the leaves. The perithecia are small; their outer wall cells are blackish-brown in color and very obscure. The asci are the smallest in the genus Sphaerotheca.

In 1900, SALMON described the fungus in question under the name of *Sphaerotheca Mors-Uvae* var. *japonica*, which was collected on *Stephanandra flexuosa* (*S. incissa*) in Prov. Rikuchu, Sept. 26, 1906, and July 7, 1907, by K. OKUMURA. Compared with *Sphaerotheca Mors-Uvae* the present species has smaller perithecia and asci. Moreover, the mycelial hyphae in *S. Mors-Uvae* are straight, smooth and thick walled, more or less shining, while in this fungus they are thin walled, flexuous and many branched. The present author has come to the conclusion that the present species had better be elevated to the specific rank rather than to be considered as a variety of *S. Mors-Uvae*

Sphaerotheca pannosa (WALLR.) LÉV.

(Pl. VII, fig. 18)

Ann. Sci. Nat. III, 15, p. 138, 1851; KICKX, Fl. Crypt. Fland. 1, p. 374, 1867; COOKE, Handb. Brit. Fung. II, p. 645, 1871; QUÉL. Champ. Jur. Vosg. p. 533, 1875; SACC. Syll. Fung. I, p. 3, 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 26, 1884; RAHM, Hedw. XXIV, p. 70, 1885; BURR. & EARLE, Bull. Ill. Stat. Lab. Nat. Hist. II, p. 398, 1887; ELL. & EVERH. N. Amer. Pyren. p. 6, 1892; SCHRÖT. in COHN's Krypt. Fl. Schles. III, p. 230, 1893; JACZEW. Bull. l'Herb. Boiss. IV, p. 726, 1896; OUDEM. Rév. Champ. Pays-Bas, II, p. 82, 1897; MAGNUS, Erysiph. Tirol. p. 5, 1898; SALM. Monogr. Erysiph. p. 65, 1900, and Bull. Torr. Bot. Club, XXIX, p. 91, 1902; NEGER, Krypt. Fl. d. Mark Brand. VII, p. 105, 1905; LIND, Danish Fung. p. 161, 1913; Doidge, Roy. Soc. South Afr. V, p. 237, 1915; KLIKA, Erysiph. Czechosl. p. 40, 1924; JØRST. Erysiph. Norway, p. 34,

1925; ŠKORIĆ, Erysiph. Croat. p. 36, 1926. (FUCK. Symb. Myc. p. 77, 1869–70; PAMM. Journ. Myc. IV, p. 37, 1888; TRACY & GALLOW. Journ. Myc. IV, p. 34, 1888; GRIFF. Bull. Torr. Bot. Club, XXVI, p. 143, 1899; RANOJ. Hedw. XLI, p. 102, 1902, and Ann. Myc. VIII, p. 355, 1910; LAWR. Journ. Myc. XI, p. 108, 1905; SHIRAI, List, p. 94, 1905; IDETA, Jap. Phytopath. p. 200, 1911; SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 44, 1914; DOIDGE, Roy. Soc. South Afr. V, p. 239, 1915; SHIRAI & MIYAKE, List, p. 629, 1917; SHIRAI & HARA, List, p. 371, 1927; HARA, Agr. Rep. Shizuoka, CCCLXIV, p. 5, 1928; MIURA, South Manch. Rwy. Co. Agr. Rep. XXVII, p. 119, 1928).

Syn. *Alphitomorpha pannosa* WALLR. Berl. Ges. Nat. Verh. I p. 43, 1819.

Erysibe pannosa SCHLECHT. Fl. Berol. II, p. 170, 1824; RABENH. Deutschl. Krypt. Fl. I, p. 230, 1844.

Erysiphe pannosa FR. Syst. Myc. III, p. 236, 1829.

Erysiphe pannosa MÉRAT. Nouv. Fl. Paris, p. 76, 1837, and Syn. Nouv. Fl. Paris, p. 84, 1837.

Podosphaera pannosa DE BARY, Beitr. Morph. Phys. Pilz. I, xiii, p. 48, 1870.

Oidium leucoconium DESM. Ann. Sci. Nat. XIII, p. 102, 1829; FR. Syst. Myc. III, p. 432, 1829; SACC. Syll. Fung. IV, p. 41, 1886; LIND. in RABENH. Krypt. Fl. Deutschl. VIII, p. 82, 1907; SAWADA, Depart. Agr. Govern. Research Inst. Formosa, no. 61, p. 80, 1933.

Amphigenous, on stems, especially shoots, mycelium persistent, forming white powdery masses throughout the summer and in late autumn turning to gray; matured conidia produced in a chain, including the well-developed fibrosin bodies, vacuolate, ellipsoidal or oblong, 20.8–24.0 × 13.2–16.0 μ.

"Perithecia more or less (usually completely) immersed in the persistent mycelium, globose to distinctly pyriform, 85–120 μ in diameter, usually about 100 μ, cells obscure, about 10 μ wide; appendages few, often obsolate, very short, tortuous, pale brown, septate; asci broadly oblong to globose, 88–115 μ, averaging 100 × 60–75 μ; spores 8, 20–27 × 12–15 μ". (Salm. Monogr. Erysiph. p. 66).

Unfortunately we could not collect the perithecial stages of this species, so that the ascogenous stage is noted from the description of SALMON.

Hab. On leaves and stems of *Rosa acicularis* LINDL. var. *Gmelini* C. K. SCHN. (Oh-takane-ibara). Hokkaido—Tokachi.

On *Rosa chinensis* JACQ. Hokkaido—Ishikari.

On *Rosa multiflora* THUNB. (Nobara). Hokkaido—Shiribeshi, Ishikari.

On *Rosa Marretii* LÉV. (Karafuto-ibara). Hokkaido—Kitami.

On *Rosa sp.* (Cult.). Hokkaido—Ishikari, Kitami. Honshu—Rikuzen, Musashi.

Distrib. Japan (Hokkaido, Honshu and Formosa), Manchuria, Europe, South Africa and North America.

Remarks. *Sphaerotheca pannosa* is very common on cultivated and wild roses, attacking their shoots, young leaves and petioles. The conidia are abundantly produced from summer to late autumn. In summer, the host plants are entirely covered with white powder. After the fall of leaves in autumn, dense velvety, mycelial masses remain here and there surrounding the shoots. This mycelium differs from the summer mycelium, by being smooth, shining, almost aseptate and about 4.8 μ in width. A part of the stem, which is attacked by this fungus suffers from hyperplasy, and several layers of loose angular-cylindrical cells are formed under the epidermal layer.

The perithecial stage of this fungus has not yet been collected in this country, in spite of the careful search for it for several years.

Oidium belonging to Sphaerotheca

On *Draba borealis* DC. var. *kurilensis* FR. SCHM. (Yezo-inunazuna). Hokkaido—Kurile Isls. Etorofu Isl.

On *Euphorbia Sieboldiana* MORR. & DECNE (Natsutodai). Saghalien—Chikahoro.

On *Heliotropium indicum* L. (Nambanruriso). Formosa— Kagi.

In 1933, the new specific name of *Oidium Heliotropii-indicii* SAW. was given for this fungus by SAWADA. (Depart. Agr. Govern. Research Inst. Formosa, Japan, No. 61, p. 80, 1933).

On *Plectranthus inflexus* VOHL. (Yama-hakka). Hokkaido—Ishikari.

On *Senecio sonchifolia* MOENCH (Usubeni-nigana).

Oidium Emiliae-sonchifoliae SAWADA (According to SAWADA, Depart. Agr. Govern. Research Inst. Formosa, Japan, No. 61, p. 79, 1933)

Podosphaera KUNZE

Mycelium persistent or evanescent; matured conidia produced in a chain 4–5 in number, ellipsoidal or subglobose, vacuolate and including well-developed fibrosin bodies; perithecia globose, dark-

brown; appendages produced from the apical or basal part of the perithecium, apices dichotomously divided 2–6 times, deep brown colored from middle downward; ascus 1; ascospores 8 in number. The species of this genus found in Japan are 4 in number, which can be divided into two sections. In one of them (Tridactyla section), the appendages are produced erectly from the upper portion of the perithecium, and in the other (Oxyacanthae section), they are produced from the basal part.

Key to the species of the genus Podosphaera

I. Tridactyla section.
Appendages arise vertically from the upper part of the perithecium.
  1. Appendages usually not branched or rarely a few times dichotomously branched.................................... *P. leucotricha* (314)
  2. Appendages dichotomously branched 3–5 times at the apex.......
  .... *P. tridactyla* (315)

II. Oxyacanthae section.
Appendages produced from the basal part of the perithecium.
  1. Appendages forming true spirals at the lower half of their length
  .... *P. spiralis* (317)
  2. Appendages straight............................... *P. Oxyacanthae* (318)

Podosphaera leucotricha (ELL. & EVERH.) SALM.

(Pl. VII, fig. 19)

Monogr. Erysiph. p. 40, 1900, and Bull. Torr. Bot. Club, XXIX, p. 86, 1902; NEGER, Krypt. Fl. d. Mark Brand. VII, p. 110, 1905; LIND, Danish Fung. p. 161, 1913; DOIDGE, Roy. Soc. South Afr. V, p. 237, 1915; KLIKA, Erysiph. Czechosl. p. 45, 1924; JØRST. Erysiph. Norway, p. 41, 1925; ŠKORIĆ, Erysiph. Croat. p. 38, 1926. (SALM. Bull. Torr. Bot. Club, XXVII, p. 445, 1900, and Ann. Myc. VI, p. 11, 1908; MATSUM. Ind. Plant. Jap. I, p. 162, 1904; IDETA, Jap. Phytopath. p. 198, 1911, and Jap. Phytopath. (Suppl. I), p. 205, 1925; SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 46, 1914; SHIRAI & MIYAKE, List, p. 469, 1917; HARA, Dendropath. p. 8, 1923; SHIRAI & HARA, List. p. 287, 1927).

Syn. *Sphaerotheca leucotricha* ELL. & EVERH. Journ. Myc. IV, p. 58, 1888; SACC. Syll. Fung. IX, p. 365, 1891.

Sphaerotheca Mali BURR. in ELL. & EVERH. N. Amer. Pyren. p. 6, 1892; MAGNUS, Ber. Deutsch. Bot. Gesell. XVI, p. 333, 1898; GROUT, Bull. Torr. Bot. Club, XXVI, p. 374, 1899.

Oidium farinosum COOKE, Grevillea, XVI, p. 10, 1887; SACC. Syll. Fung. X, p. 520, 1892; LIND. in RABENH. Krypt. Fl. Deutschl. VIII, p. 83, 1907.

Amphigenous, mostly epiphyllous, also on shoots and especially on the apical part of branches: mycelium persistent or evanescent; matured conidia borne in a chain, vacuolate, granulate, including the well-developed fibrosin bodies, ellipsoidal, 25.2–28.8 × 15.6–19.2 μ; perithecia small, gregarious, 70.8–81.6 μ in diameter, blackish-brown, globose or subglobose; cells indistinct, 13.2–16.8 × 10.8–14.4 μ wide; erect appendages produced at the upper part of the perithecium, straight or more or less curved, apex always simple or very rarely dichotomously branched, dark-brown colored almost throughout their length, rarely hyaline at the apex, 224–367 μ long, 3–8 septate; ascus 1, globose or subglobose, without stalk, 54.2–69.6 × 49.2–64.8 μ; spores 8, oblong or ovate, 21.6–24.0 × 12.0–16.8 μ.

Hab. On leaves and stems of *Malus baccata* BORCKH. var. *mandschurica* SCHNEID. (Yezo-no-koringo). Hokkaido—Ishikari.

On *Malus pumila* MILL. var. *domestica* SCHNEID. (Seiyo-ringo). Hokkaido—Ishikari. Honshu—Mutsu.

Distrib. Japan (Hokkaido, Honshu and Formosa), Manchuria, Europe, South Africa, Australia and North America.

Remarks. *Podosphaera leucotricha* had been included in the genus Sphaerotheca by many authors, but, in 1900, SALMON placed it in Podosphaera because of the fact that the appendages are rarely dichotomously divided at the apex.

In the present species, two forms of appendages are known, one the apical, and the other the basal type. The former type is produced from the apical part of the perithecium and it is always simple, and erect, but very rarely dichotomously divided at the apex. The latter is produced from the basal part of the perithecium and it is similar in form to the mycelial hyphae.

Podosphaera tridactyla (WALLR.) DE BARY

(Pl. VII, fig. 20)

Beitr. Morph. Phys. Pilz. I, xiii, p. 48, 1870; SACC. Syll. Fung. I, p. 2, 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 28, 1884; SCHRÖT. in COHN's Krypt. Fl. Schles. III, p. 233, 1893; JACZEW. Bull. l'Herb. Boiss. IV, p. 744, 1896; PRILL. Malad. Pl. Agr. II, p. 33, 1897;

MAGNUS, Erysiph. Tirol. p. 10, 1898; NEGER, Krypt. Fl. d. Mark Brand. VII, p. 110, 1905; LIND, Danish Fung. p. 161, 1913; KLIKA, Erysiph. Czechosl. p. 45, 1924; JØRST. Erysiph. Norway, p. 50, 1925; ŠKORIĆ, Erysiph. Croat. p. 39, 1926. (YOSHINO, Bot. Mag. Tokyo, XIX, p. 206, 1905; IDETA, Jap. Phytopath. p. 199, 1911, and Jap. Phytopath. (Suppl. I), p. 207, 1923; SYD. Ann. Myc. XI, p. 113, 1913; SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 47, 1914, and XIX, p. 162, 1919; HARA, Dendropath. p. 7, 1923; SHIRAI & HARA, List, p. 287, 1927).

Syn. *Alphitomorpha tridactyla* WALLR. Fl. Crypt. Germ. II, p. 753, 1833.

Erysibe tridactyla RABENH. Deutschl. Krypt. Fl. I, p. 237, 1844.

Erysibe Brayana RABENH. Deutschl. Krypt. Fl. I, p. 237, 1844.

Podosphaera Kunzei LÉV. Ann. Sci. Nat. III, 15, p. 135 (p.p.), 1851; KICKX, Fl. Crypt. Fland. I, p. 376, 1867; COOKE, Handb. Brit. Fung. II, p. 647, 1871; COOKE & PECK, Journ. Bot. I, p. 11, 1872; QUÉL. Champ. Jur. Vosg. p. 534, 1875. (FUCK. Symb. Myc. p. 77, (p.p.) 1869–70).

Erysiphe tridactyla TULASNE, Selecta Fung. Carpolog. I, p. 201, 1861.

Podosphaera Oxyacanthae (not DE BARY) BURR. & EARLE, Bull. Ill. Stat. Lab. Nat. Hist. II, p. 412, (p.p.), 1887. (STEVENS, Journ. Myc. XIII, p. 69, 1907).

Podosphaera Oxyacanthae (DC.) DE BARY var. *tridactyla* (WALLR.) SALM. Monogr. Erysiph. p. 36, 1900, and Bull. Torr. Bot. Club, XXIX, p. 85, 1902. (SALM. Bull. Torr. Bot. Club,XXVII, p. 445, 1900, Ann. Myc. III, p. 251, 1905, and VI, p. 11, 1908; MATSUM. Ind. Plant. Jap. I, p. 162, 1904; LAWR. Journ. Myc. XI, p. 107, 1906; SHIRAI, List, p. 71, 1905; SHIRAI & MIYAKE, List, p. 469, 1917).

Oidium erysiphoides FR. Syst. Myc. III, p. 432 (p.p.), 1829; SACC. Syll. Fung. IV, p. 41 (p.p.), 1886; LIND. in RABENH. Krypt. Fl. Deutschl. VIII, p. 79 (p.p.), 1907.

Amphigenous, mostly epiphyllous; mycelium evanescent, at first forming a thin effused film; matured conidia borne in a chain, vacuolate, including the well-developed fibrosin bodies, subglobose or ellipsoidal, 16.8–32.4 × 10.8–18.0 μ; perithecia small, 84–98 μ in diameter; cells 13.2–15.6 μ wide; appendages produced from the upper part of the perithecium, erect, often fasciculate, 2–5 in number, straight or more or less curved, 154–175 μ in length, aseptate or 1–3 septate,

deep brown colored to half their length or more, dichotomously branched 4–6 times at the apex, usually 5 times, primary or secondary branches are longer than the others, the apex of the ultimate branches more or less recurved; ascus 1, oblong, with a short stalk, 60.0–70.8 × 53.6–57.6 μ; spores 8, ellipsoidal or elongate-ellipsoidal, 19.2–26.4 × 12.0–14.4 μ.

Hab. On leaves of *Prunus Armeniaca* L. var. *Ansu* MAXIM. (Anzu). Honshu—Musashi.

On *Prunus Buergeriana* MIQ. (Inu-zakura). Honshu—Musashi.

On *Prunus Cerasus* L. (Mizakura). Hokkaido—Iburi. Honshu—Rikuchu.

On *Prunus Grayana* MAXIM. (Uwamizu-zakura). Honshu—Rikuchu, Hitachi.

On *Prunus Mume* SIEB. & ZUCC. (Mume). Hokkaido—Ishikari. Honshu—Musashi, Hitachi, Etchu, Yamashiro.

On *Prunus Padus* L. (Yezo-no-uwamizu-zakura). Saghalien—Izutsu-kawara.

On *Prunus Persica* SIEB. & ZUCC. var. *vulgaris* MAXIM. (Momo). Honshu—Musashi.

On *Prunus serrulata* LINDL. var. *albida* MAKINO subvar. *speciosa* MAKINO (Ohshima-zakura). Honshu—Musashi.

On *Prunus triflora* ROXB. (Sumomo). Hokkaido—Shiribeshi, Ishikari. Honshu—Musashi, Echigo.

On *Prunus yedoensis* MATSUM. (Someiyoshino). Honshu—Musashi, Echigo.

Distrib. Japan (Saghalien, Hokkaido, Honshu and Formosa), Manchuria, Europe and North America.

Remarks. The present species is widely found on different species of the genus Prunus. In the character of the appendages which are produced from the upper part of the perithecium, it is easily distinguished from *Podosphaera Oxyacanthae* in which the appendages are basal.

Podosphaera spiralis MIYABE

(Pl. VII, fig. 21)

In IDETA, Jap. Phytopath. p. 199, 1911. (SYD. Ann. Myc. XI, p. 113, 1913; SHIRAI & MIYAKE, List, p. 471, 1917; SHIRAI & HARA, List, p. 287, 1927).

Hypophyllous, mycelium evanescent; perithecia gregarious or subgregarious, 84.0–105.6 μ in diameter; cells 12.0–16.8 × 9.6–12.0 μ in size; appendages 2–8 in number, produced from the basal part of the perithecium, forming sinistrorse spirals, 3–4 times in the lower

half of their length, 77.0–126 μ long, dark brown colored throughout or hyaline from middle upward, usually 2–3 septate, rarely aseptate, dichotomously branched 2–3 times, (rarely 4 times), tips of the ultimate branches broad, recurved or not; ascus 1, subglobose or ovate, short stalked, 72.0–98.4 × 57.2–81.6 μ; spores 8, rarely 7, oblong or ovate, 21.2–26.4 × 14.4–16.8 μ.

Hab. On leaves of *Ulmus propinqua* KOIDZ. (Harunire). Hokkaido—Ishikari.

Distrib. Japan (Hokkaido).

Remarks. This species is endemic to Japan. It can readily be distinguished from other species of Podosphaera, by the spiral appendages of the perithecium and by the larger ascus.

Podosphaera spiralis is found on the leaves of Ulmus bush, frequently associated with *Uncinula clandestina*, which occurs on the upper surface of the leaves, while the present fungus is always found on the under surface. The mycelium of the latter entirely disappears when the perithecia are formed so that it is very difficult to find it. This very interesting species was first collected and named by Prof. MIYABE.

Podosphaera Oxyacanthae (DC.) DE BARY

(Pl. VII, fig. 22)

Beitr. Morph. Phys. Pilz. I, xiii, p. 48, 1870; SACC. Syll. Fung. I, p. 2, 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 29, 1884; EARLE, Bot. Gaz. IX, p. 26, 1884; BURR. & EARLE, Bull. Ill. Stat. Lab. Nat. Hist. II, p. 412 (p.p.), 1887; ELL. & EVERH. N. Amer. Pyren. p. 21, 1892; SHRÖT. in COHN's Krypt. Fl. Schles. II, p. 234, 1893; JACZEW. Bull. l'Herb. Boiss. IV, p. 743, 1896; MAGNUS, Erysiph. Tirol. p. 10, 1898; SALM. Monogr. Erysiph. p. 29, 1900, and Bull. Torr. Bot. Club, XXIX, p. 83, 1902; NEGER, Krypt. Fl. d. Mark Brand. VII, p. 112, 1905; KLIKA, Erysiph. Czechosl. p. 44, 1924; JØRST. Erysiph. Norway, p. 47, 1925; ŠKORIĆ, Erysiph. Croat. p. 40, 1926; TAI & WEI, Sinensia, III, p. 121, 1932. (GALLOW. Journ. Myc. IV, p. 34, 1888; PAMM. Journ. Myc. IV, p. 38, 1888; GRIFF. Bull. Torr. Bot. Club, XXVI, p. 143, 1899; SALM. Bull. Torr. Bot. Club, XXVII, p. 455, 1900, Ann. Myc. III, p. 251, 1905, and VI, p. 11, 1908; MATSUM. Ind. Plant. Jap. I, p. 162, 1904; LAWR. Journ. Myc. XI, p. 107, 1905; SHIRAI, List, p. 71, 1905; IDETA, Jap. Phytopath. p. 198, 1911;

JAAP, Ann. Myc. IX, p. 333, 1911; SAWADA, Agric. Exp. Stat. Formosa, Bull. IX, p. 48, 1914; I. MIYAKE, Bot. Mag. Tokyo, XXVIII, p. 39, 1914; SHIRAI & MIYAKE, List, p. 469, 1917; HARA, Dendropath. p. 8, 1923; SHIRAI & HARA, List, p. 287, 1927).

Syn. *Erysiphe Oxyacanthae* DC. Fl. Fr. VI, p. 106, 1815; TULASNE, Selecta Fung. Carpolog. I, p. 202, 1861.

Erysibe clandestina LK. in WILLD. Sp. Pl. VI, p. 103, 1824; RABENH. Deutschl. Krypt. Fl. I, p. 237, 1844.

Erysiphe clandestina (*Oxyacanthae*) FR. Syst. Myc. III, p. 238, 1829.

Podosphaera clandestina LÉV. Ann. Sci. Nat. III, 15, p. 136, 1851; KICKX, Fl. Crypt. Fland. I, p. 376, 1867; COOKE, Handb. Brit. Fung. II, p. 648, 1871; QUÉL. Champ. Jur. Vosg. p. 534, 1875; LIND, Danish Fung. p. 161, 1913. (FUCK. Symb. Myc. p. 77, 1869–70).

Podosphaera Kunzei LÉV. Ann. Sci. Nat. III, 15, p. 135 (p.p.), 1851; COOKE & PECK, Journ. Bot. I, p. 170, 1872.

Podosphaera minor E. C. HOWE, Bull. Torr. Bot. Club, V, p. 3, 1874; SACC. Syll. Fung. IX, p. 364, 1891.

Microsphaera fulvofulcra COOKE, Grevillea, V, p. 110, 1877; SACC. Syll. Fung. I, p. 14, 1882.

Oidium Crataegi GROG. in ROUMEG. Fung. Gall. No. 881, 1888; LIND. in RABENH. Krypt. Fl. Deutschl. VIII, p. 82, 1907; SACC. Syll. Fung. XXII, p. 1249, 1913.

Amphigenous, mycelium evanescent or subpersistent, forming thin and effused film; perithecia scattered or subgregarious, globose, 70.0–88.0 μ in diameter; cells 11.8–19.0 $\times$ 10.0–13.6 μ in width; appendages produced from the basal part of the perithecium, 8–16 in number, straight or more or less curved throughout, thin walled, dark brown colored from middle downward, 84–126 μ, aseptate, 4–5 times dichotomously branched at the apex, ultimate branches broad and recurved or not; ascus 1, subglobose or broadly ovate, 58.6–60.0 $\times$ 45.6–48.0 μ, without stalk; spores 7–8, rarely 5, including remarkably well developed fibrosin bodies, oblong or ellipsoidal, 24.0–28.8 $\times$ 12.0–14.4 μ.

Hab. On leaves of *Crataegus chlorosarca* MAXIM. (Kuromi-sanzashi). Saghalien—Otani, Konuma.

On *Crataegus jozana* C. K. SCHN. (Yezo-sanzashi). Hokkaido—Ishikari.

On *Crataegus Maximowiczii* SCHNEID. (Arage-akasanzashi). Saghalien—Otatomari, Ruikofu.

On *Spiraea betulifolia* PALL. (Maruba-shimotsuke). Saghalien—Tonnai. Hokkaido—Ishikari.

On *Spiraea salicifolia* L. var. *lanceolata* TORR. & GRAY. (Hozaki-shimotsuke). Saghalien—Kamiarumudan. Hokkaido—Iburi.

Distrib. Japan (Saghalien, Hokkaido, Honshu and Formosa), China, Europe and North America.

Remarks. *Podosphaera Oxyacanthae* which is known as the cherry powdery mildew or apple mildew is injurious especially to the young stock of nurseries.

Podosphaera myrtillina is included in this species as a synonym by SALMON, but the examination of the form on *Vaccinium uliginosum* has shown that the diameter of the perithecia is larger, being 112 μ and the appendages are very long, reaching about 840 μ in length. These characters are sufficient to distinguish it from *Podosphaera Oxyacanthae*.

Erysiphe HEDW. f.

Mycelium is superficial, sending haustoria into the epidermal cells of the host plants; haustoria are subglobose or finger-like in shape (graminis); matured conidia are produced in a chain or solitary and fibrosin bodies are wanting; perithecia are globose; appendages of the perithecium are simple; asci and ascospores are several.

This genus can be divided into three sections, Polygoni (*Erysiphe Polygoni, E. Heraclei, E. Pisi, E. Aquilegiae*), Cichoracearum (*Erysiphe Cichoracearum, E. Galeopsidis*), and Graminis (*Erysiphe graminis*). These sections can be identified by the characters of their conidia. In the Polygoni section, the matured conidia are solitary; in the Cichoracearum section, they are always produced in a chain; and in the Graminis section, they are in a long chain and there is a bulbous swelling at the base of the conidiophore.

Key to the species of the genus Erysiphe

I. Polygoni section.
Matured conidia solitary, ascospores 3–8 in an ascus.
- A. Appendages hyaline or pale brown colored at the base.
  1. Appendages simple .... ***E. Pisi*** (321)
  2. Appendages vaguely branched and flexuous ..... ***E. Heraclei*** (324)
- B. Appendages colored.
  1. Appendages simple, brown colored from middle downward .... ***E. Polygoni*** (326)

2. Appendages deep brown colored throughout at maturity, flexuous and vaguely branched .... *E. Aquilegiae* (330)

II. Graminis section.
Matured conidia produced in a chain, having a bulbous swelling at the base of the conidiophore, ascospores 3–8 .... *E. graminis* (333)

III. Cichoracearum section.
Matured conidia borne in a chain, ascospores 2, rarely 3.

1. Ascospores are matured on the living host plants .... *E. Cichoracearum* (335)
2. Ascospores remain immatured on the living host plants .... *E. Galeopsidis* (340)

Erysiphe Pisi DC.

(*Pl. VII, figs. 23, 24, and Pl. VIII, figs. 1, 2*)

Fl. Fr. II, p. 274, 1805. (RANOJ. Ann. Myc. VIII, p. 356, 1910).

Syn. *Alphitomorpha communis* WALLR. Berl. Ges. Nat. Freund. Verh. I, p. 31 (p.p.), 1819; PRILL. Malad. Pl. Agr. III, p. 14, 1897.

Erysibe Pisi DC. in GRAY. Nat. Arr. Brit. Pl. I, p. 589, 1821; SCHRÖT. in COHN's Krypt. Fl. Schles. II, p. 236, 1893. (JAAP, Ann. Myc. IX, p. 333, 1911).

Erysiphe communis FR. Syst. Myc. III, p. 239 (p.p.), 1829; KICKX, Fl. Crypt. Fland. I, p. 380 (p.p.), 1867; SACC. Syll. Fung. I, p. 18 (p.p.), 1882; BURR. & EARLE, Ill. Stat. Lab. Nat. Hist. II, p. 402 (p.p.), 1887; ELL. & EVERH. N. Amer. Pyren. p. 10 (p.p.), 1892; OUDEM. Rév.Champ. Pays-Bas, II, p. 97 (p.p.), 1897; LIND, Danish Fung. p. 162 (p.p.), 1913. (TRACY & GALL. Journ. Myc. IV, p. 34 (p.p.), 1888; PAMM. Journ. Myc. IV, p. 37 (p.p.), 1888; GRIFF. Bull. Torr. Bot. Club, XXVI, p. 141 (p.p), 1899; SHIRAI, List, p. 32 (p.p), 1905; SHIRAI & MIYAKE, List, p. 223 (p.p.), 1917).

Erysibe communis LK. in RABENH. Deutschl. Krypt. Fl. I, p. 223 (p.p.), 1844.

Erysiphe communis MÉRAT, Nouv. Fl. Paris, p. 75 (p.p.), 1837, and Syn. Nouv. Fl. Paris, p. 84 (p.p.), 1837.

Erysiphe communis (not FR.) DE BARY, Beitr. Morph. Phys. Pilz. I, xiii, p. 50 (p.p.), 1870.

Erysiphe communis (not FR.) COOKE, Handb. Brit. Fung. II, p. 652 (p.p.), 1871.

Erysiphe Martii LÉV. Ann. Sci. Nat. III, 15, p. 166 (p.p.), 1851; COOKE, Handb. Brit. Fung. II, p. 651 (p.p.), 1871; SACC. Syll. Fung. I, p. 19 (p.p.), 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2,

p. 31 (p.p.), 1884; JACZEW. Bull. l'Herb. Boiss. IV, p. 729 (p.p.), 1896; OUDEM. Rév. Champ. Pays-Bas, II, p. 97 (p.p.), 1897; MAGNUS, Erysiph. Tirol. p. 13 (p.p.), 1898. (FUCK. Symb. Myc. p. 83 (p.p.), 1869–70).

Erysiphe communis (not FR.) QUÉL. Champ. Jur. Vosg. p. 532 (p.p.), 1875.

Erysiphe Polygoni (not DC.) SALM. Monogr. Erysiph. p. 174 (p.p.), 1900, and Bull. Torr. Bot. Club, XXIX, p. 181 (p.p.), 1902; NEGER, Krypt. Fl. d. Mark Brand. VII, p. 118 (p.p.), 1905; KLIKA, Erysiph. Czechosl. p. 66 (p.p.), 1924; TAI & WEI, Sinensia, III, p. 96 (p.p.), 1932. (SALM. Bull. Torr. Bot. Club, XXVII, p. 443 (p.p.), 1900, Ann. Myc. III, p. 249 (p.p.), 1905, and VI, p. 8 (p.p.), 1908; MATSUM. Ind. Plant. Jap. I, p. 141 (p.p.), 1904; LAWR. Journ. Myc. XI, p. 106 (p.p.), 1905; YOSHINO, Bot. Mag. Tokyo, XIX, p. 205 (p.p.), 1905; IDETA, Jap. Phytopath. p. 204 (p.p.), 1911; I. MIYAKE, Bot. Mag. Tokyo, XXVI, p. 53, 1912; DOIDGE, Roy. Soc. South Afr. V, p. 241 (p.p.), 1915; SHIRAI & MIYAKE, List, p. 225 (p.p.), 1917).

Erysibe Pisi DC. var. *Desmodii* P. HENN. in ENGR. Bot. Jahrb. XXIX, p. 148, 1901. (SHIRAI, List, p. 32, 1905; SHIRAI & MIYAKE, List, p. 227, 1917).

Erysiphe communis (not FR.) RANOJ. Hedw. XLI, p. 102, 1902.

Microsphaera Polygoni SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 53 (p.p.), 1914, and XIX, p. 168 (p.p.), 1919. (SHIRAI & MIYAKE, List, p. 367 (p.p.), 1917; IDETA, Jap. Phytopath. (Suppl. I), p. 210 (p.p.), 1923; SHIRAI & HARA, List, p. 217 (p.p.), 1927; MIURA, Pub. South. Manch. Rwy. Co. XXVII, p. 135 (p.p.), 1928).

Amphigenous, mostly hypophyllous, also on petioles and stems; mycelium persistent or subpersistent, white powdery at first, turning to greyish color when mature; matured conidia solitary, vacuolate, elongate oblong or ellipsoidal, 36.0–50.4 × 12.0–19.2 μ in size; perithecia scattered, globose or depressed-globose, 93.6–140 μ in diameter (on *Diervilla japonica* 116–168 μ); cells 8.4–16.8 × 9.6–21.6 μ in size; appendages simple, mostly hyaline, rarely pale brown to the first septum, 8–22 in number, flaccid or flexuous, 266–462 μ in length, aseptate or 1–5 septate; asci hyaline or rarely light yellow, 4–9 in number, oblong or ovate, with a short stalk, thick walled, 51.6–74.4 × 31.2–57.6 μ; spores hyaline, 3–8 in number, ellipsoidal or ovate, 15.6–25.2 × 9.6–16.8 μ.

Hab. On leaves and stems of *Alnus pendula* MATSUM. (Hime-yashabushi). Honshu—Rikuchu.

On *Aeschynomene indica* L. (Kusa-nemu). Honshu—Inaba.

On *Astragalus reflexistipulus* MIQ. (Momenzuru). Hokkaido—Ishikari.

On *Astragalus secundus* DC. (Rishiri-wogi). Hokkaido—Ishikari.

On *Desmodium caudatum* DC. var. *japonicum* NAKAI (Nusubito-hagi). Hokkaido—Oshima. Honshu—Musashi, Sagami. Shikoku—Tosa. Kyushu—Higo.

On *Falcata japonica* KOM. (Yabumame). Hokkaido—Oshima, Shiribeshi, Iburi, Ishikari. Honshu—Rikuchu, Musashi, Echigo, Etchu, Kaga, Mino. Kyushu—Buzen, Higo.

On *Indigofera pseudo-tinctoria* MATSUM. (Komatsunagi). Honshu—Musashi.

On *Indigofera tinctoria* L. (Kiai). Kyushu—Higo.

On *Lathyrus maritimus* BIGEL. (Hama-endo). Hokkaido—Ishikari.

On *Lespedeza bicolor* TURCZ. var. *japonica* NAKAI (Hagi). Honshu—Etchu.

On *Lespedeza cuneata* G. DON. (Medo-hagi). Honshu—Kazusa. Kyushu—Higo.

On *Lespedeza pilosa* SIEB. & ZUCC. (Neko-hagi). Honshu—Musashi, Yamashiro. Kyushu—Higo.

On *Lespedeza virgata* DC. (Makie-hagi). Honshu—Musashi, Hitachi.

On *Lotus corniculatus* L. var. *japonicus* REGEL (Miyakogusa). Hokkaido—Iburi.

On *Lupinus perennis* L. (Hauchiwa-mame). Hokkaido—Ishikari.

On *Medicago lupulina* L. (Kibana-no-kometsubu-umagoyashi). Hokkaido—Ishikari.

On *Microlespedeza stipulacea* MAKINO (Yahazuso). Honshu—Etchu.

On *Phaseolus Mungo* L. (Ke-tsuru-azuki). Honshu—Musashi.

On *Phaseolus radiatus* L. var. *aurea* PRAIN. (Azuki). Kyushu—Higo.

On *Pisum sativum* L. (Endo). Hokkaido—Oshima, Ishikari, Kitami. Honshu—Rikuzen, Musashi, Tamba. Kyushu—Higo.

On *Sophora angustifolia* SIEB. & ZUCC. (Kurara). Honshu—Bizen, Hoki.

On *Thermopsis fabacea* DC. (Sendaihagi). Honshu—Musashi.

On *Trifolium incarnatum* L. (Kurimuson-kuroba). Hokkaido—Ishikari.

On *Trifolium repens* L. (Kuroba). Hokkaido—Ishikari.

On *Vigna sinensis* SAVI (Sasage). Kyushu—Higo. Formosa—Shinchiku.

On *Diervilla decora* NAKAI (Nishiki-utsugi). Honshu—Kaga.

On *Diervilla japonica* DC. (Tani-utsugi). Hokkaido—Ishikari. Honshu—Ugo, Sagami, Echigo.

Distrib. All over the world.

Remarks. In this species the appendages are hyaline, simple, more or less straight and scarcely distinguishable from the mycelium. The great number of Leguminosae and a small part of Betulaceae and Caprifoliaceae are included as host plants of the species in this country.

Erysiphe Pisi was first recorded by DE CANDOLLE as a species causing the powdery mildew on Leguminosae. Since then, it was con-

sidered as the synonym of *Erysiphe communis* or *E. Martii*, and in 1900, SALMON included it under *Erysiphe Polygoni* together with the above mentioned two species.

As the result of careful examination, the author has found that it differs from *E. Polygoni* in that the appendages are almost hyaline and simple.

In 1901, P. HENNINGS (78) treated the fungus on *Desmodium podocarpum* var. *latifolium*, as a new variety of *E. Pisi* DC. (*E. Pisi* DC. var. *Desmodii* P. HENN.—Prov. Musashi: Mt. Takao, Oct. 18, 1899, S. KUSANO). The co-type specimen was kindly given to the author by Prof. S. KUSANO, who kindly informed her that the host plant was not *Desmodium* but *Falcata japonica*. As the result of studies on this specimen as well as on the numerous specimens of the same fungus on *Falcata japonica* which had been collected in different parts of this country, we have found that there is no need of keeping the var. *Desmodii*, as it is essentially the same in characters as *E. Pisi*.

The forms on *Vicia Cracca* and *Robinia pseudacacia* have hitherto been included in this species, but they had better be included in Microsphaera, as the appendages are regularly dichotomously branched once or twice.

In the form on *Medicago lupulina*, the cells of the perithecial walls are large, being 18.0–21.6 × 12.0–16.8 μ in size.

In the form on *Astragalus reflexistipulus*, the asci and ascospores are small, the asci being 40.8–52.8 × 30.0–39.6 μ and the ascospores 18.0–20.4 × 10.4–12.0 μ in size.

In the form on *Diervilla japonica*, the perithecium attains a large size, being 110–168 μ in diameter.

The form on the fruit of *Alnus pendula* is very interesting in that the fungus could not be distinguished from *E. Pisi*, as the appendages of the perithecium are hyaline or pale brown toward the base and always simple. As the result of the comparison with *Erysiphe aggregata* on Alnus, the present fungus is found to have smaller perithecia and asci.

Erysiphe Heraclei DC.

(Pl. VIII, figs. 3, 4, 5)

Fl. Fr. VI, p. 107, 1815. (RANOJ. Ann. Myc. VIII, p. 356, 1910).
Syn. *Erysiphe Scandicis* DC. Fl. Fr. VI, p. 107, 1815.

Erysiphe communis FR. Syst. Myc. III, p. 239 (p.p.), 1829; LIND, Danish Fung. p. 162 (p.p.), 1913. (SHIRAI, List, p. 32 (p.p.), 1905; SHIRAI & MIYAKE, List, p. 223, 1917).

Erysibe communis LK. in RABENH. Deutschl. Krypt. Fl. I, p. 233 (p.p.), 1844.

Erysiphe communis MÉRAT. Nouv. Fl. Paris, p. 75 (p.p.), 1837, and Syn. Nouv. Fl. Paris, p. 84 (p.p.), 1837.

Erysiphe Martii LÉV. Ann. Sci. Nat. III, 15, p. 166 (p.p.), 1851; KICKX, Fl. Crypt. Fland. I. p. 382, 1867; COOKE, Handb. Brit. Fung. II, p. 651 (p.p.), 1871; SACC. Syll. Fung. I, p. 19 (p.p.), 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 31 (p.p.), 1884; JACZEW. Bull. l'Herb. Boiss. IV, p. 729 (p.p.), 1896. (FUCK. Symb. Myc. p. 83 (p.p.), 1869–70).

Erysiphe Umbelliferarum DE BARY, Beitr. Morph. Phys. Pilz. I, xiii, p. 50, 1870; SACC. Syll. Fung. I, p. 17, 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 31, 1884; MAGNUS, Erysiph. Tirol. p. 13, 1898.

Erysiphe Martii LK. in QUÉL. Champ. Jur. Vosg. p. 532 (p.p.), 1875.

Erysibe Heraclei DC. *in* SCHRÖT. COHN'S Krypt. Fl. Schles. III, p. 239, 1893. (JAAP, Ann. Myc. IX, p. 333, 1911).

Erysiphe communis Fr. var. *Umbelliferarum* JACZEW. Bull. l'Herb. Boiss. IV, p. 733, 1896.

Erysiphe Polygoni (not DC.) SALM. Monogr. Erysiph. p. 174 (p.p.), 1900, Bull. Torr. Bot. Club, XXVII, p. 443 (p.p.), 1900, and XXIX, p. 181 (p.p.), 1902; NEGER, Krypt. d. Mark Brand. VII, p. 118 (p.p.), 1905; KLIKA, Erysiph. Czechosl. p. 66 (p.p.), 1924. (MATSUM. Ind. Plant. Jap. I, p. 141 (p.p.), 1904; SALM. Ann. Myc. III, p. 249 (p.p.), 1905, and VI, p. 8 (p.p.), 1908; P. HENN. in ENGL. Bot. Jahrb. XXXII, p. 41, 1903, and XXXIV, p. 600, 1905; YOSHINO, Bot. Mag. Tokyo, XIX, p. 205 (p.p.), 1905; SYD. Ann. Myc. VII, p. 170, 1909, and XI, p. 113, 1913; IDETA, Jap. Phytopath. p. 204 (p.p.), 1911; SHIRAI & MIYAKE, List, p. 225 (p.p.), 1917).

Microsphaera Polygoni SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 53 (p.p.), 1914, and XIX, p. 168 (p.p.), 1919. (SHIRAI & MIYAKE, List, p. 367 (p.p.), 1917; HARA, Dendropath. p. 13, 1923; IDETA, Jap. Phytopath. (Suppl. I), p. 210 (p.p.), 1923; SHIRAI & HARA, List, p. 217 (p.p.), 1927).

Amphigenous, also on stems, petioles and inflorescences; mycelium evanescent; matured conidia solitary, vacuolate, granulate, ellipsoidal or elongate-ellipsoidal, 33.6–45.6 ×16.8–18.0 μ; perithecia globose or depressed-globose, 84–136 μ in diameter; cells 12.0–21.6 × 8.4–13.2 μ in size; appendages irregular in form and length, 14–17 in number, aseptate or 1–2 septate, about 188–210 μ long, hyaline, light brown colored toward the base, sometimes irregularly branched at the apex; asci 4–6, subglobose or ellipsoidal, evidently stalked, 40.8–62.4 × 30.0–43.2 μ; spores 3–6, ellipsoidal, oblong or ovate, 19.2–39.6 × 9.6–14.4 μ. (The size of three spores in an ascus is larger than that of the others).

Hab. On leaves and stems of *Quercus glauca* THUNB. (Ara-gashi). Honshu—Kii, Yamashiro, Kawachi, Inaba. Shikoku—Tosa. Kyushu—Hizen, Higo.

On *Quercus myrsinaefolia* BLUME (Shira-kashi). Honshu—Bitchu.

On *Quercus stenophylla* MAKINO (Urajiro-gashi). Honshu—Aki.

On *Fagopyrum esculentum* MOENCH. (Soba). Hokkaido—Ishikari. Honshu—Hitachi, Etchu. Kyushu—Hizen, Higo.

On *Angelica Miqueliana* MAXIM. (Yama-zeri). Honshu—Musashi.

On *Peucedanum terebinthaceum* FISCH. (Kawara-bofu). Hokkaido—Ishikari.

On *Seseli Libanotis* KOCH. (Hama-ibuki-bofu). Hokkaido—Iburi. Honshu—Ugo.

On *Torilis Anthriscus* BERNK. (Yabu-jirami). Hokkaido—Shiribeshi, Iburi, Ishikari, Kushiro.

Distrib. All over the world.

Remarks. The present species can be distinguished from *Erysiphe Pisi* by the fact that the appendages of the perithecium are very irregularly branched and numerous in number.

Erysiphe Polygoni DC.

(Pl. VIII, figs. 6, 7, 8)

Fl. Fr. II, p. 273, 1805; SALM. Monogr. Erysiph. p. 174 (p.p.), 1900, and Bull. Torr. Bot. Club, XXIX, p. 181 (p.p.), 1902; NEGER, Krypt. d. Mark Brand. VII, p. 118 (p.p.), 1905; KLIKA, Erysiph. Czechosl. p. 66 (p.p.), 1924; TAI & WEI, Sinensia, III, p. 96 (p.p.), 1932. (SALM. Bull. Torr. Bot. Club, XXVII, p. 443 (p.p.), 1900, Ann. Myc. III, p. 249 (p.p.), 1905, and VI, p. 8 (p.p.), 1908; MATSUM. Ind. Plant. Jap. I, p. 141 (p.p.), 1904; LAWR. Journ. Myc. XI, p. 106

(p.p.), 1905; IDETA, Jap. Phytopath. p. 204 (p.p.), 1911; I. MIYAKE, Bot. Mag. Tokyo, XXVIII, p. 39, 1914; SHIRAI & MIYAKE, List, p. 225 (p.p.), 1917; TOGASHI, Jap. Journ. Bot. II, p. 79, 1924).

Syn. *Erysiphe Convolvuli* DC. Fl. Fr. II, p. 274, 1805.

Alphitomorpha communis WALLR. Berl. Ges. Nat. Freuend. Verh. I, p. 31 (p.p.), 1819.

Erysibe Polygoni DC. in GRAY, Nat. Arr. Brit. I, p. 589, 1821; SCHRÖT. in COHN's Krypt. Fl. Schles. III, p. 234, 1893; P. HENN. in ENGL. Bot. Jahrb. XXIX, p. 148, 1901.

Erysiphe communis FR. Syst. Myc. III, p. 239 (p.p.), 1829; KICKX, Fl. Crypt. Fland. I, p. 380 (p.p.), 1867; SACC. Syll. Fung. I, p. 18 (p.p.), 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 32 (p.p.), 1884; BURR. & EARLE, Ill. Stat. Lab. Nat. Hist. II, p. 402 (p.p.), 1887; ELL. & EVERH. N. Amer. Pyren. p. 10 (p.p.), 1892; MAGNUS, Erysiph. Tirol. p. 15 (p.p.), 1895; JACZEW. Bull. l'Herb. Boiss. IV, p. 732 (p.p.), 1896; OUDEM. Rév. Champ. Pays-Bas, II, p. 97 (p.p.), 1897; LIND, Danish Fung. p. 162 (p.p.), 1913. (FUCK. Symb. Myc. p. 85 (p.p.), 1869–70; TRACY et GALLOW. Journ. Myc. IV, p. 34 (p.p.), 1888; GRIFF. Bull. Torr. Bot. Club, XXVI, p. 141 (p.p.), 1899; P. HENN. in ENGL. Bot. Jahrb. XXVIII, p. 272, 1901; MATSUM. Ind. Plant. Jap. I, p. 141, 1904; SHIRAI, List, p. 32 (p.p.), 1905; SHIRAI & MIYAKE, List, p. 223, 1917).

Erysibe communis LK. in RABENH. Deutschl. Krypt. Fl. I, p. 233 (p.p.), 1844.

Erysiphe communis MÉRAT, Nouy. Fl. Paris, p. 75 (p.p.), 1837.

Erysiphe Martii LÉV. Ann. Sci. Nat. III, 15, p. 166 (p.p.), 1851; JACZEW. Bull. l'Herb. Boiss. IV, p. 729 (p.p.), 1896.

Erysiphe communis DE BARY, Beitr. Morph. Phys. Pilz. I, xiii, p. 50 (p.p.), 1870.

Erysiphe Martii LK. in QUÉL. Champ. Jur. Vosg. p. 532 (p.p.), 1875.

Erysiphe Polygoni SCHRÖT. in RANOJ. Ann. Myc. VIII, p. 356, 1910.

Microsphaera Polygoni SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 53 (p.p.), 1914. (SAWADA, Agr. Exp. Stat. Formosa, Bull. XIX, p. 168 (p.p.), 1919; IDETA, Jap. Phytopath. (Suppl. I), p. 210 (p.p.), 1923; SHIRAI & HARA, List, p. 217 (p.p.), 1927; MIURA, Pub. South Manch. Rwy. Co. XXVII, p. 135 (p.p.), 1928).

Ovularia Clematidis CHITT. Gard. Chron. p. 299, 1903.

Oidium Clematidis SACC. & TRAV. in SACC. Syll. Fung. XXII, p. 1249, 1913.

Amphigenous, also on stems and petioles; mycelium persistent, at first forming white mycelial patches and finally spreading over the surface of the leaves and stems; matured conidia solitary, vacuolate, granulate, elongate-ellipsoidal or oblong, 31.2–42.0 × 12.0–16.8 μ (except the form on *Elsholtzia Patrini*); perithecia scattered or gregarious, 84–140 μ in diameter, globose or depressed-globose; cells 9.6–25.2 × 8.4–16.8 μ in size; appendages variable in number, 1–5 times the diameter of the perithecia, several septate or rarely aseptate, brown colored from middle downward, always simple; asci hyaline or light yellow, 4–10, oblong or ovate, evidently stalked, 38.4–70.4 × 26.4–48.0 μ; spores 3–6 in number, elongate-ellipsoidal, 14.4–28.8 × 8.0–16.8 μ.

Hab. On leaves, stems and inflorescence of *Pilea viridissima* MAKINO (Aomizu). Hokkaido—Ishikari, Kushiro.

On *Polygonum aviculare* L. (Michiyanagi). Saghalien—Baguntan. Hokkaido—Oshima, Shiribeshi, Ishikari, Teshio, Kushiro. Honshu—Rikuchu, Musashi, Echigo. Shikoku—Tosa.

On *Aconitum kamtschaticum* WILLD. (Chishima-torikabuto). Hokkaido—Kurile Isls. Etorofu Isl.

On *Clematis alpina* MILL. (Miyama-hanshozuru). Hokkaido—Ishikari.

On *Clematis fusca* TURCZ. var. *mandshurica* TAKEDA (Kurobana-hanshozuru). Hokkaido—Ishikari.

On *Clematis paniculata* THUNB. (Senninso). Honshu—Aki. Shikoku—Tosa.

On *Macleya cordata* R. BR. (Takeni-gusa). Honshu—Musashi.

On *Sedum Aizoon* L. (Hosobano-kirinso). Saghalien—Akashiki. Hokkaido—Iburi.

On *Sedum alboroseum* BAK. (Benkei-so). Hokkaido—Ishikari, Kushiro. Honshu—Musashi, Etchu.

On *Sedum Telephium* L. var. *purpureum* L. (Murasaki-benkeiso). Saghalien—Akashiki. Hokkaido—Ishikari.

On *Saxifraga cortusaefolia* SIEB. & ZUCC. var. *typica* MAKINO (Daimonjiso). Hokkaido—Ishikari.

On *Linum usitatissimum* L. (Ama). Hokkaido—Ishikari.

On *Abelmoschus esculentus* MOENCH. (Tororo-aoi). Honshu—Etchu.

On *Lythrum Salicaria* L. (Yezo-misohagi). Hokkaido—Ishikari, Kushiro.

On *Clinopodium chinense* KUNTZE (Kurumabana). Hokkaido—Ishikari.

On *Clinopodium sachalinense* KOIDZ. (Miyama-kurumabana). Hokkaido—Tokachi. Honshu—Etchu.

On *Elsholtzia Patrini* GARCKE (Naginata-koju). Hokkaido—Iburi, Ishikari, Kitami, Tokachi, Kushiro. Honshu—Mutsu, Rikuchu.

On *Scutellaria dependens* MAXIM. (Hime-namiki). Saghalien—Alexandrowsk. Hokkaido—Shiribeshi, Ishikari. Honshu—Echigo.

On *Scutellaria galericulata* L. var. *pubescens* REGEL (Oh-namiki). Saghalien—Odomari.

On *Scutellaria scordifolia* FISCH. f. *puberula* KOM. (Yezo-namiki). Hokkaido—Ishikari.

On *Scutellaria strigillosa* HEMSL. (Namikiso). Hokkaido—Shiribeshi.

On *Scutellaria ussuriensis* KUDO (Yezo-tatsunamiso). Hokkaido—Iburi, Ishikari, Kushiro.

On *Mimulus inflatus* NAKAI (Mizo-hoozuki). Hokkaido—Shiribeshi, Ishikari, Kitami, Kushiro.

On *Actinostemma lobatum* MAXIM. var. *racemosum* MAK. (Gokizuru). Honshu—Musashi, Kazusa. Shikoku—Tosa. Kyushu—Higo.

On *Schizopepon bryoniaefolius* MAXIM. (Miyama-nigauri). Hokkaido—Kushiro.

On *Trichosanthes cucumeroides* MAXIM. (Karasu-uri). Honshu—Echigo.

On *Cacalia delphinifolia* SIEB. & ZUCC. (Momijigasa). Hokkaido—Ishikari.

Distrib. All over the world.

Remarks. The powdery mildew parasitic on *Polygonaceae* was named *Erysiphe Polygoni* by DE CANDOLLE. Afterward, a large number of host plants have been gradually added to the fungus by many authors. In 1900, SALMON (32) considered *Erysiphe Polygoni* as a very large collective species, the number of its host plants amounting to about 350 species and synonyms to about 50 in number having been attributed to the species. The writer has carefully examined every specimen on the host plants belonging to 84 species collected in the different parts of this country. As the result of the examination, the writer has come to the conclusion that SALMON's *Erysiphe Polygoni* could be divided into four types by the characters of the appendages (*Erysiphe Pisi*, *E. Heraclei*, *E. Polygoni* and *E. Aquilegiae*), although all of them have 3–8 spores in an ascus.

In the present species, the appendages are simple and brown colored from the middle downward.

In 1914, *Erysiphe Polygoni* was transferred to *Microsphaera Polygoni* by SAWADA (149) because of the following points; the conidia are solitary and the apex of the appendages is frequently divided once or twice. From what the present writer has examined, she does not hesitate to transfer the form on *Vicia Cracca* and *Vicia unijuga* to Microsphaera, but in the forms on other host plants she considers it better to retain them in the genus Erysiphe.

In the form on *Elsholtzia Patrini*, the conidia differ from others in respect to their subglobose form, and smaller size, 28.8–30.0 × 19.2–

22.8 μ, also the appendages include many granules and they are very evidently 4–7 septate.

In the form on *Aconitum kamtschaticum*, although the forms on other species of Aconitum belong to *Erysiphe Aquilegiae*, the appendages are light brown colored at the base, and always simple, the asci and ascospores are larger, the asci being 45.6–70.4 × 30.0–48.0 μ and the ascospores 22.4–26.4 × 12.0–16.8 μ.

In the form on *Sedum Telephium*, the ascospores are subglobose and the appendages are difficult to distinguish from the mycelium, as they are both brown colored.

Erysiphe Aquilegiae DC.

(Pl. VIII, figs. 9, 10, 11)

Fl. Fr. VI, p. 105, 1815.

Syn. *Alphitomorpha communis* WALLR. Berl. Ges. Nat. Freund. Verh. I, p. 31 (p.p.), 1819.

Erysiphe communis FR. Syst. Myc. III, p. 239 (p.p.), 1829; KICKX, Fl. Crypt. Fland. I, p. 380 (p.p.), 1867; DE BARY, Beitr. Morph. Phys. Pilz. I, xiii, p. 50 (p.p.), 1870; SACC. Syll. Fung. I, p. 18 (p.p.), 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 32 (p.p.), 1884; BURR. & EARLE, Ill. Stat. Lab. Nat. Hist. II, p. 402 (p.p.), 1887; ELL. & EVERH. N. Amer. Pyren. p. 10 (p.p.), 1892; JACZEW. Bull. l'Herb. Boiss. IV, p. 732 (p.p.), 1896; OUDEM. Rév. Champ. Pays-Bass, II, p. 97 (p.p.), 1897; MAGNUS, Erysiph. Tirol. p. 15 (p.p.), 1898; LIND, Danish Fung. p. 162 (p.p.), 1913. (FUCK. Symb. Myc. p. 85 (p.p.), 1869–70; TRACY & GALLOW. Journ. Myc. IV, p. 34 (p.p.), 1888; PAMM. Journ. Myc. IV, p. 37 (p.p.), 1888; GRIFF. Bull. Torr. Bot. Club, XXVI, p. 141 (p.p.), 1899; SHIRAI, List, p. 32 (p.p.), 1905; SHIRAI & MIYAKE, List, p. 223 (p.p.), 1917).

Erysibe communis LK. in RABENH. Deutschl. Krypt. Fl. I, p. 233 (p.p.), 1844.

Erysiphe communis MÉRAT, Nouv. Fl. Paris, p. 75 (p.p.), 1837.

Erysibe nitida (*delphinii*) RABENH. Deutschl. Krypt. Fl. I, p. 231, 1844.

Erysiphe communis SCHL. ex. COOKE, Handb. Brit. Fung. II, p. 652 (p.p.), 1871; COOKE & PECK, Journ. Bot. I, p. 13, 1872, and I, p. 171, 1872.

Erysiphe vernalis KARST. Myc. Fenn. II, p. 193, 1874; SACC. Syll. Fung. I, p. 19, 1882.

Erysiphe communis QUÉL. (not FR.) Champ. Jur. Vosg. p. 532 (p.p.), 1875.

Erysiphe communis FR. f. *Paeoniae* RAHM, Hedw. XXIV, p. 70, 1885.

Erysiphe Polygoni (not DC.), SALM. Monogr. Erysiph. p. 174 (p.p.), 1900, Bull. Torr. Bot. Club, XXVII, p. 443 (p.p.), 1900, and XXIX, p. 181 (p.p.), 1902; NEGER, Krypt. d. Mark. Brand. VII, p. 118 (p.p.), 1905; KLIKA, Erysiph. Czechosl. p. 66 (p.p.), 1924. (MATSUM. Ind. Plant. Jap. I, p. 141 (p.p.), 1904; LAWR. Journ. Myc. XI, p. 106 (p.p.), 1905; SALM. Ann. Myc. III, p. 249 (p.p.), 1905, and VI, p. 8 (p.p.), 1908; IDETA, Jap. Phytopath. p. 204 (p.p.), 1911; SHIRAI & MIYAKE, List, p. 225 (p.p.), 1917).

Erysibe Polygoni DC. in JAAP, Ann. Myc. IX, p. 333, 1911.

Microsphaera Polygoni SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 53 (p.p.), 1914. (IDETA, Jap. Phytopath. (Suppl. I), p. 210 (p.p.), 1923; SHIRAI & HARA, List, p. 217 (p.p.), 1927).

Amphigenous, also on petioles, stems and calyxes; mycelium persistent or evanescent, grayish colored; matured conidia solitary, vacuolate, granulate, ellipsoidal or elongate-ellipsoidal, 28.8–40.0 × 15.8–16.8 μ; perithecia gregarious, imbedded in the mycelial mass, globose or depressed-globose, 70–144 μ in diameter; cells 13.2–27.5 × 8.4–16.8 μ in size; appendages 11–49 in number, dark brown colored from the base to the apex or light brown colored toward the apex, aseptate or 1–4 septate, of the same width throughout, 98–490 μ long; asci 3–6, subglobose or ovate, with a short stalk, thick-walled, 43.2–62.4 × 28.8–42.8 μ; spores 2–7 in number, usually 3, ellipsoidal or oblong, 16.8–26.4 × 8.4–14.4 μ.

Hab. On leaves and stems of *Alnus pendula* MATSUM. (Hime-yashabushi). Honshu—Rikuchu.

On *Aconitum Fischeri* REICHB. (Hiroha-no-karafuto-bushi). Saghalien—Toyohara.

On *Aconitum gigas* LEV. & VNT. (Oh-reijinso). Saghalien—Tsumanai.

On *Aconitum japonica* THUNB. (Torikabuto). Honshu—Rikuchu.

On *Aconitum yezoense* NAKAI (Yezo-torikabuto). Saghalien—Otani. Hokkaido—Shiribeshi, Ishikari, Teshio, Kitami, Hidaka.

On *Actaea acuminata* WALL. (Ruiyo-shoma). Honshu—Echigo.

On *Aquilegia flabellata* SIEB. & ZUCC. (Odamaki). Hokkaido—Ishikari.

On *Aquilegia flabellata* SIEB. & ZUCC. f. *pumila* KUDO (Okumiyama-odamaki). Saghalien—Mt. Tosso. Hokkaido—Ishikari.

On *Caltha palustris* L. f. *gigas* LÉV. (Yezo-no-ryukinkwa). Saghalien—Shisuka, Konuma. Hokkaido—Iburi, Tokachi, Hidaka.

On *Caltha palustris* L. var. *procumbens* BECK. (Hai-ryukinkwa). Hokkaido—Kurile Isls. Kunashiri Isl.

On *Caltha palustris* L. var. *sibirica* REGEL f. *decumbens* MAKINO (Yenkoso). Saghalien—Nueuo.

On *Paeonia albiflora* PALL. var. *hortensis* MAKINO (Shakuyaku). Hokkaido—Ishikari.

On *Paeonia japonica* MIYABE & TAKEDA (Shirobana-yamashakuyaku). Hokkaido—Ishikari.

On *Ranunculus acris* L. var. *Steveni* REGEL (Miyama-kimpoge). Hokkaido—Kurile Isls. Etorofu Isl.

On *Ranunculus japonicus* LANGSD. (Kitsune-no-botan). Hokkaido—Shiribeshi, Ishikari. Honshu-Rikuzen.

On *Ranunculus repens* L. (Hai-kimpoge). Saghalien—Makunkotan, Kitanayoshi.

On *Thalictrum akanense* HUTH. (Miyama-akikaramatsu). Hokkaido—Ishikari, Kitami, Kushiro.

On *Thalictrum Thunbergii* NAKAI (Aki-karamatsu). Saghalien—Toyohara, Ambetsu, Mt. Suzuya. Hokkaido—Shiribeshi, Ishikari, Tokachi, Kushiro. Honshu—Rikuchu.

On *Cirsium Grayanum* NAKAI (Maruba-hire-azami). Hokkaido—Ishikari.

On *Cirsium schantarense* TRAUTV. & MEY. (Okuyezo-azami). Saghalien—Kita-nayoshi.

On *Cirsium Weyrichii* MAXIM. (Yezo-azami). Saghalien—Oioro, Kushunnai, Mt. Kashippo.

Distrib. All over the world.

Remarks. In this fungus, the appendages are deep brown colored throughout. In comparison with *Erysiphe Polygoni*, the appendages in the present species are more numerous, nearly blackish brown colored when mature, and moreover, are flexuous and irregularly branched.

The forms on *Aconitum yezoense* and *A. japonicum* resemble *E. Polygoni* in that the appendages are light brown colored in the young stages, but turn deep brown when mature.

In the form on *Caltha palustris*, the appendages are numerous and very deep brown colored from the base to the apex.

Erysiphe graminis DC.

(Pl. VIII, fig. 12)

Fl. Fr. VI, p. 106, 1815; LÉV. Ann. Sci. Nat. III, 15, p. 165, 1851; KICKX, Fl. Crypt. Fland. I, p. 383, 1867; COOKE, Handb. Brit. Fung. II, p. 651, 1871; COOKE & PECK, Journ. Bot. I, p. 13, 1872; QUÉL. Champ. Jur. Vosg. p. 531, 1875; SACC. Syll. Fung. I, p. 19, 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I. 2, p. 30, 1884; ELL. & EVERH. N. Amer. Pyren. p. 15, 1892; JACZEW. Bull. l'Herb. Boiss. IV, p. 728, 1896; OUDEM. RÉV. Champ. Pays-Bas, II, p. 98, 1897; PRILL. Malad. Pl. Agr. II, p. 9, 1897; MAGNUS, Erysiph. Tirol. p. 12, 1898; SALM. Monogr. Erysiph. p. 209, 1900, and Bull. Torr. Bot. Club, XXIX, p. 195, 1902; NEGER, Krypt. Fl. d. Mark Brand. VII, p. 114, 1905; LIND, Danish Fung. p. 161, 1913; KLIKA, Erysiph. Czechosl. p. 62, 1924; ŠKORIĆ, Erysiph. Croat. p. 95, 1926; TAI & WEI, Sinensia, III, p. 95, 1932. (FUCK. Symb. Myc. p. 83, 1869–70; TRACY & GALLOW. Journ. Myc. IV, p. 35, 1888; GRIFF. Bull. Torr. Bot. Club, XXVI, p. 142, 1899; SALM. Bull. Torr. Bot. Club, XXVII, p. 443, 1900, Ann. Myc. III, p. 249, 1905, and VI, p. 8, 1908; P. HENN. in ENGL. Bot. Jahrb. XXXII, p. 42, 1903; MATSUM. Ind. Plant. Jap. I, p. 141, 1904; LAWR. Journ. Myc. XI, p. 106, 1905; SHIRAI, List, p. 32, 1905; YOSHINO, Bot. Mag. Tokyo, XIX, p. 205, 1905; RANOJ. Ann. Myc. VIII, p. 357, 1910; IDETA, Jap. Phytopath. p. 203, 1911, and Jap. Phytopath. (Suppl. I), p. 200, 1923; DOIDGE, Roy. Soc. South Afr. p. 242, 1915; SAWADA, Agric. Exp. Stat. Formosa, Bull. IX, p. 35, 1914, and XIX, p. 145, 1919; SHIRAI & MIYAKE, List, p. 223, 1917; SHIRAI & HARA, List, p. 132, 1927; MIURA, Pub. South Manch. Rwy. Co. XXVII, p. 124, 1928).

Syn. *Alphitomorpha communis* var. *graminearum* WALLR. Berl. Ges. Nat. Freund. Verh. I, p. 31, 1819.

Erysiphe communis FR. Syst. Myc. III, p. 239 (p.p.), 1829.

Erysiphe communis MÉRAT, Nouv. Fl. Paris, p. 75 (p.p.), 1837.

Erysibe communis LK. in RABENH. Deutschl. Krypt. Fl. I, p. 232 (p.p.), 1844.

Erysibe graminis DC. in SCHRÖT. in COHN'S Krypt. Fl. Schles. III, p. 240, 1893. (JAAP, Ann. Myc. IX, p. 333, 1911).

Acrosporium monilioides NEES, Syst. Pilz. u. Schwam. p. 53, 1817; UNGER, Exantheme d. Pflanz. p. 389, 1833.

Oidium monilioides LINK, Sp. Pl. I, p. 122, 1824; FR. Syst. Myc. III, p. 431, 1829; SACC. Syll. Fung. IV, p. 46, 1886; LIND. in RABENH. Krypt. Fl. Deutschl. VIII, p. 78, 1907, and IX, p. 724, 1910.

Torula tritici CORD. Icon. Fung. V, p. 51, 1842.

Torula bulbigera BON. Bot. Zeitung, XIX, p. 195, 1861.

Oidium monilioides LINK, var. *ochraceum* THÜM. Fung. Austr. n. 1804, 1874; SACC. Syll. Fung. IV, p. 46, 1886; LIND. in RABENH. Krypt. Fl. Deutschl. VIII, p. 79, 1907.

Oidium Tritici SACC. et VOGL. Syll. Fung. IV, p. 46, 1886.

Oidium bulbigerum SACC. et VOGL. Syll. Fung. IV, p. 47, 1886.

Amphigenous, mostly epiphyllous, also on glumes and sheaths; mycelium persistent, at first white mycelial hyphae appear along the vein, but finally turn to a grayish colored, thick cushion, hyphal cells comparatively broad, smooth and shining; matured conidia produced in a chain, having a bulbous swelling at the base of the conidiophore, vacuolate, granulate, ellipsoidal or elongate-ellipsoidal, 22.8–46.8 × 10.8–20.4 μ; perithecia gregarious or scattered, imbedded in the mycelial masses, depressed-globose or concave, 174–224 μ in diameter, blackish brown colored when mature; cells obscure, 13.2–14.4 × 8.4–9.6 μ in size; appendages about 11 in number, shorter than the diameter of the perithecium, light brown colored at the base, simple, aseptate; asci about 11 in number, elongate-ovate, 73.2–93.6 × 24.0–38.4 μ, with a stalk; spores always 8, subglobose or broad-ellipsoidal, 14.4–19.2 × 9.6–14.4 μ in size.

Hab. On leaves, glumes and sheaths of *Agropyrum ciliare* FRANCH. (Kamoji-gusa). Honshu—Musashi, Echigo, Bizen.

On *Agropyrum repens* BEAUV. (Shibamugi). Saghalien—Shisuka.

On *Brachypodium miserum* KOIDZ. (Yama-kamoji-gusa). Shikoku—Iyo. Kyushu—Hizen, Higo.

On *Bromus japonicus* THUNB. (Suzumeno-chahiki). Honshu—Rikuchu.

On *Elymus mollis* TRIN. (Tenki-gusa). Hokkaido—Kushiro.

On *Hordeum sativum* JESS. var. *hexastichon* L. (Hadaka-mugi). Hokkaido—Shiribeshi, Ishikari. Honshu—Shinano. Shikoku—Awa.

On *Hordeum sativum* JESS. var. *vulgare* HACK. (Oh-mugi). Hokkaido—Iburi, Ishikari. Honshu—Musashi, Echigo, Owari, Yamashiro, Harima, Bizen, Bitchu. Shikoku—Iyo. Kyushu—Hizen, Higo.

On *Poa annua* L. (Suzumeno-katabira). Honshu—Etchu.

On *Poa pratensis* L. (Nagaha-gusa). Saghalien—Kita-nayoshi. Hokkaido—Ishikari.

On *Poa sphondylodes* TRIN. var. *strictula* KOIDZ. (Ichigo-tsunagi). Saghalien—Shisuka.

On *Stipa sibirica* LAM. var. *japonica* HACK. (Hirohano-hanegaya). Hokkaido—Shiribeshi, Ishikari.

On *Trisetum flavescens* BEAUV. var. *genuinum* HACK. (Chishima-kanitsuri). Saghalien—Shisuka.

On *Triticum sativum* LAM. var. *vulgare* HACK. (Komugi). Hokkaido—Ishikari. Honshu—Musashi, Shinano, Bitchu.

Distrib. Japan (Saghalien, Hokkaido, Honshu, Shikoku, Kyushu and Formosa), China, Manchuria, India, Europe, South Africa and North America.

Remarks. This species is a very common powdery mildew on Gramineae. On wheat and barley, it appears especially more luxuriously on the pot culture materials in the green house than in the field. In the forms on wheat, barley and *Agropyrum ciliare*, the mycelial patches are at first white, but finally they turn to a gray color and form thick velvety masses. In the form on *Poa pratensis*, however, the mycelium retains its white color throughout all stages.

Erysiphe graminis differs distinctly from other species of Erysiphe in respect to its conidiophore having a bulbous swelling at the base, and besides, in respect to its haustoria which have several finger-like branches on one or both sides, and are larger in size than those of other species. These characters have not been found in other species of Erysiphaceae.

Many specialized forms have been recorded in this species; namely, *E. graminis* f. sp. *Tritici* MARCHAL, f. sp. *Hordei* MARCHAL, f. sp. *Secalis* MARCHAL, f. sp. *Avenae* MARCHAL, f. sp. *Poae* MARCHAL, f. sp. *Agropyri* MARCHAL, f. sp. *Bromi* MARCHAL and f. sp. *Elymi* HOMMA. In these forms, the mean values which the writer has measured on the conidia, 500 in number, for the length and the width are as follows:

f. sp. *Tritici*	37.35 ± 0.037	14.5 ± 0.035
f. sp. *Hordei*	35.45 ± 0.078	14.64 ± 0.04
f. sp. *Poae*	31.00 ± 0.045	16.31 ± 0.043
f. sp. *Agropyri*	33.26 ± 0.088	15.74 ± 0.047
f. sp. *Elymi*	26.67 ± 0.144	13.84 ± 0.068

Erysiphe Cichoracearum DC. (Emend Wint.)

(Pl. VIII, figs. 13, 14)

Fl. Fr. II, p. 274, 1805; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 33, 1884; BURR. & EARLE, Ill. Stat. Lab. Nat. Hist. II, p. 404,

1887; ELL. & EVERH. N. Amer. Pyren. p. 12, 1892; MAGNUS, Erysiph. Tirol. p. 17, 1897; SALM. Monogr. Erysiph. p. 193, 1900, and Bull. Torr. Bot. Club, XXIX, p. 191, 1902; NEGER, Krypt. Fl. d. Mark Brand. VII, p. 116, 1905; LIND, Danish Fung. p. 162, 1913; KLIKA, Erysiph. Czechosl. p. 64, 1924; ŠKORIĆ, Erysiph. Croat. p. 46, 1926; TAI & WEI, Sinensia, III, p. 93, 1932. (TRACY & GALLOW. Journ. Myc. IV, p. 34, 1888; PAMM. Journ. Myc. IV, p. 37, 1888; GRIFF. Bull. Torr. Bot. Club, XXVI, p. 141, 1899; SALM. Bull. Torr. Bot. Club, XXVII, p. 443, 1900, Ann. Myc. III, p. 249, 1905, and VI, p. 8, 1908; MATSUM. Ind. Plant. Jap. I, p. 140, 1904; P. HENN. in ENGL. Bot. Jahrb. XXXIV, p. 600, 1905; YOSHINO, Bot. Mag. Tokyo, XIX, p. 205, 1905; SHIRAI, List, p. 31, 1905; LAWR. Journ. Myc. XI, p. 106, 1905; NAMBU, Bot. Mag. Tokyo, XX, p. 250, 1906; RANOJ. Ann. Myc. VIII, p. 356, 1910; IDETA, Jap. Phytopath. p. 205, 1911, and Jap. Phytopath. (Suppl. I), p. 199, 1923; I. MIYAKE, Bot. Mag. Tokyo, XXVI, p. 53, 1912; SAWADA, Agric. Exp. Stat. Formosa, Bull. IX, p. 31, 1914, and XIX, p. 139, 1919; DOIDGE, Roy. Soc. South Afr. V, p. 241, 1915; SHIRAI & MIYAKE, List, p. 221, 1917; TOGASHI, Jap. Journ. Bot. II, p. 78, 1924; SHIRAI & HARA, List, p. 131, 1927; MIURA, Pub. South Manch. Rwy. Co. XXVII, p. 122, 1928; HARA, Agr. Rep. Shizuoka, CCCLXIV, p. 6, 1928).

Syn. *Alphitomorpha communis*, var. *Cichoracearum* WALLR. Berl. Ges. Nat. Freund. Verh. I. p. 31, 1819.

Erysibe lamprocarpa var. *Plantaginis* LINK, in WILLD. Sp. Pl. VI, p. 109, 1824.

Erysiphe communis FR. Syst. Myc. III, p. 239 (p.p.), 1829; LIND, Danish Fung. p. 162 (p.p.), 1913.

Erysiphe communis MÉRAT, Nouv. Fl. Paris, p. 75 (p.p.), 1837.

Erysiphe compositarum DUBY, Bot. Gall. II, p. 870, 1830; MÉRAT, Nouv. Fl. Paris, p. 75, 1837, and Syn. Nouv. Fl. Paris, p. 84, 1837.

Erysiphe lamprocarpa MÉRAT, Nouv. Fl. Paris, p. 75 (p.p.), 1837, and Syn. Nouv. Fl. Paris, p. 84 (p.p.), 1837.

Erysibe communis LK. in RABENH. Deutschl. Krypt. Fl. I, p. 232 (p.p.), 1844.

Erysibe circumfusa LK. in RABENH. Deutschl. Krypt. Fl. I, p. 232 (p.p.), 1844.

Erysibe depressa LK. in RABENH. Deutschl. Krypt. Fl. I, p. 232, 1844.

Erysibe lamprocarpa RABENH. Deutschl. Krypt. Fl. I, p. 232 (p.p.), 1844.

Erysibe horridula RABENH. Deutschl. Krypt. Fl. I, p. 235, 1844.

Erysiphe lamprocarpa LÉV. Ann. Sci. Nat. III, 15, p. 163 (p.p.), 1851; DE BARY, Beitr. Morphor. Phys. Pilz. I, xiii, p. 49, 1870; COOKE, Handb. Brit. Fung. II, p. 650, 1871; COOKE & PECK, Journ. Bot. I, p. 13, 1872, and I, p. 171, 1872; QUÉL. Champ. Jur. Vosg. p. 532, 1875; JACZEW. Bull. l'Herb. Boiss. IV, p. 730, 1896; OUDEM. Rév. Champ. Pays-Bas, II, p. 94, 1897. (FUCK. Symb. Myc. p. 82, 1869–70).

Erysiphe Linkii LÉV. Ann. Sci. Nat. III, 15, p. 161, 1851; COOKE, Handb. Brit. Fung. II, p. 650, 1871; QUÉL. Champ. Jur. Vosg. p. 532, 1875; SACC. Syll. Fung. I, p. 16, 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I. p. 30, 1884; JACZEW. Bull. l'Herb. Boiss. IV, p. 727, 1896; OUDEM. Rév. Champ. Pays-Bas, II, p. 93, 1897; MAGNUS, Erysiph. Tirol. p. 12, 1898. (FUCK. Symb. Myc. p. 82, 1869–70).

Erysiphe Montagnei LÉV. Ann. Sci. Nat. III, 15, p. 169, 1851; COOKE, Handb. Brit. Fung. II, p. 651, 1871; QUÉL. Champ. Jur. Vosg. p. 532, 1875; SACC. Syll. Fung. I, p. 17, 1882.

Erysiphe Martii LÉV. Ann. Sci. Nat. III, 15, p. 166 (p.p.), 1851; MAGNUS, Erysiph. Tirol. p. 13 (p.p.), 1898.

Erysiphe horridula LÉV. Ann. Sci. Nat. III, 15, p. 170, 1851; KICKX, Fl. Crypt. Fland. I, p. 381, 1867; COOKE, Handb. Brit. Fung. II, p. 652, 1871; SACC. Syll. Fung. I, p. 17, 1882; OUDEM. Rév. Champ. Pays-Bas, II, p. 96, 1897.

Erysiphe spadicea BERK. & CURT. Grevillea, IV, p. 159, 1876; SACC. Syll. Fung. I, p. 18, 1882.

Erysibe Cichoracearum DC. in SCHRÖT. COHN's Krypt. Fl. Schles. III, p. 238, 1893.

Erysiphe lamprocarpa KICKX, Fl. Crypt. Fland. p. 382, 1897.

Erysiphe Plantaginis SAWADA, Agric. Exp. Stat. Formosa, Bull. XXIV, p. 47, 1927; MIURA, Pub. South Manch. Rwy. Co. XXVII, p. 125, 1928. (SHIRAI & HARA, List, p. 132, 1927).

Oidium erysiphoides FR. Syst. Myc. III, p. 432 (p.p.), 1829; SACC. Syll. Fung. IV, p. 41 (p.p.), 1886; LIND. in RABENH. Krypt. Fl. Deutschl. VIII, p. 79 (p.p.), 1907.

Oidium Chrysanthemi RABENH. Hedw. I, p. 19, 1862; SACC. Syll. Fung. IV, p. 43, 1886; LIND. in RABENH. Krypt. Fl. Deutschl. VIII, p. 87, 1907.

Amphigenous, also on petioles, stems and fruits, mycelium persistent or subevanescent; matured conidia produced in a chain, subglobose or ellipsoidal, vacuolate, granulate, 24.0–43.2 × 14.4–26.4 μ; perithecia gregarious or rarely sub-scattered, 84–168 μ in diameter, globose or depressed-globose; cells 12.0–33.6 × 8.4–20.4 μ; appendages 13–35 in number, very irregular in length and forms, 1–6 times the diameter of the perithecia, brown colored from the base to the apex or gradually becoming a light color or hyaline in the upper part, 1–6 septate, simple, rarely irregularly or dichotomously branched; asci 5–15 in number, ellipsoidal, evidently stalked, 43.2–74.4 × 25.2–45.6 μ; spores always 2, sometimes 3, very rarely 1, subglobose or ovate, 16.8–31.2 × 12.0–19.2 μ.

Hab. On leaves, petioles, stems and fruits of *Laportea bulbifera* WEDD. (Mukago-irakusa). Hokkaido—Shiribeshi, Ishikari.

On *Arabis pendula* L. (Yezo-hatazao). Saghalien—Arakai, Tomioka, Tei.

On *Brassica campestris* L. var *rapifera* METZG. (Aburana). Hokkaido—Ishikari.

On *Cardamine flexiosa* WITH. (Tanetsuke-bana). Hokkaido—Ishikari.

On *Raphanus sativus* L. (Daikon). Hokkaido—Ishikari.

On *Polemonium coeruleum* L. var. *laxiflorum* MIYABE & MIYAKE (Karafuto-hanashinobu). Saghalien—Kami-arumudan, Kita-nayoshi.

On *Polemonium coeruleum* L. var. *racemosum* MIYABE & KUDO (Kushiro-hanashinobu). Saghalien—Shisuka.

On *Polemonium coeruleum* L. var. *yezoense* MIYABE & KUDO (Yezo-hanashinobu). Hokkaido—Ishikari.

On *Serratula coronata* L. (Tamuraso). Honshu—Rikuzen, Musashi. Shikoku—Tosa. Kyushu—Higo.

On *Nicotiana alata* LINK. & OTTO (Shikukon-tabako). Honshu—Musashi.

On *Nicotiana Tabacum* L. (Tabako). Kyushu—Higo. Formosa—Daihoku.

On *Physalis Francheti* MAST. var. *Bunyardii* MAKINO (Hoozuki). Hokkaido—Ishikari. Honshu—Hitachi, Musashi, Echigo, Etchu, Kaga. Shikoku—Tosa. Kyushu—Satsuma.

On *Physaliastrum echinatum* MAK. (Iga-hoozuki). Honshu—Ugo. Shikoku—Tosa.

On *Scopolia japonica* MAXIM. (Hashiri-dokoro). Honshu—Etchu.

On *Solanum Melongena* L. (Nasu). Honshu—Etchu.

On *Solanum nigrum* L. (Inu-hoozuki). Hokkaido—Ishikari.

On *Plantago kamtschatica* LINK (Yezo-ohbako). Hokkaido—Shiribeshi, Tokachi. Honshu—Mutsu.

On *Plantago lanceolata* L. (Hera-ohbako). Hokkaido—Shiribeshi.

On *Plantago major* L. var. *asiatica* DECNE (Ohbako). Saghalien—Sakaehama, Ochiai, Alexandrowsk, Kita-nayoshi, Tsumanai, Maoka, Minami-nayoshi, Konuma. Hokkaido—Kurile Isls. Shikotan Isl., Oshima, Shiribeshi, Iburi, Ishi-

kari, Teshio, Kitami, Tokachi, Hidaka, Kushiro. Honshu—Rikuchu, Rikuzen, Uzen, Musashi, Shimozuke, Echigo, Etchu, Echizen, Kaga, Shima. Shikoku—Iyo. Kyushu—Bungo, Higo, Hiuga.

On *Galium Aparine* L. (Yaemugura). Hokkaido—Ishikari.

On *Galium verum* L. var. *lacteum* MAXIM. (Kawara-matsuba). Hokkaido—Ishikari.

On *Galium verum* L. var. *typicum* MAXIM. (Kibana-no-kawara-matsuba). Saghalien—Makunkotan.

On *Adenophora Thunbergiana* KUDO (Tsurigane-ninjin). Honshu—Musashi.

On *Achillea millefolium* L. (Seiyo-nokogiriso). Hokkaido—Shiribeshi. Honshu—Etchu.

On *Achillea Ptarmicoides* MAXIM. (Yama-nokogiri). Kyushu—Higo.

On *Achillea sibirica* LEDEB. (Nokogiriso). Hokkaido—Ishikari. Kyushu—Higo.

On *Artemisia japonica* THUNB. (Otoko-yomogi). Hokkaido—Oshima, Shiribeshi, Iburi, Ishikari, Tokachi, Kushiro. Kyushu—Higo.

On *Artemisia japonica* THUNB. var. *desertorum* MAXIM. (Hosoba-otoko-yomogi). Saghalien—Maoka. Hokkaido—Ishikari.

On *Artemisia vulgaris* L. var. *indica* MAXIM. (Yomogi). Honshu—Musashi Echigo, Etchu, Echizen. Kyushu—Higo.

On *Artemisia vulgaris* L. var. *kamtschatica* BESS. (Yezo-yomogi). Saghalien—Nayoshi, Pilewo, Akashiki, Manue, Maoka, Konuma. Hokkaido—Shiribeshi, Iburi, Ishikari, Kitami, Tokachi, Kushiro.

On *Artemisia vulgaris* L. var. *latiloba* LEDEB. (Hiroha-urajiro-yomogi) Saghalien—Mt. Tosso.

On *Aster Laulureanus* FRANCH. (Yomena). Honshu—Musashi, Etchu.

On *Chrysanthemum Marschalii* ASCHERS. (Aka-mushiyoke-giku). Hokkaido—Ishikari. Honshu—Shimozuke. Kyushu—Higo.

On *Chrysanthemum sinense* SABIN. var. *hortense* MAKINO (Kiku). Hokkaido—Ishikari.

On *Cirsium Weyrichii* MAXIM. (Yezo-azami). Saghalien—Makunkotan, Mt Tosso.

On *Inula salicina* L. (Kasenso). Hokkaido—Iburi, Ishikari.

On *Matricaria Chamomilla* L. (Kamitsure). Hokkaido—Ishikari.

On *Picris hieracioides* L. var. *japonica* REGEL (Kozorina). Saghalien—Kushunnai, Ochiai, Kita-nayoshi, Kami-kiminai, Konuma. Hokkaido—Ishikari Kitami, Tokachi, Kushiro. Honshu—Shinano.

On *Scorzonera radiata* FISCH. (Futanamiso). Saghalien—Nucuo.

On *Solidago Virgaurea* L. (Akino-kirinso). Hokkaido—Ishikari. Honshu—Rikuchu.

On *Sonchus arvensis* L. var. *uliginosus* TRAUTV. (Hachijona). Saghalien—Konuma. Hokkaido—Ishikari, Tokachi.

On *Sonchus asper* VILL. (Oni-nogeshi). Honshu—Echigo.

On *Sonchus oleraceus* L. (Nogeshi). Honshu—Musashi, Oki. Kyushu—Higo, Hiuga.

On *Tanacetum vulgare* L. (Yomogigiku). Hokkaido—Ishikari.

Distrib. Japan (Saghalien, Hokkaido, Honshu, Shikoku, Kyushu and Formosa), Manchuria, India, Europe, Africa, Australia and North America.

Remarks. The present species is a very common powdery mildew spread all over the world. The Japanese name of *Udonkokin* is originated from this species.

The writer has examined every specimen on the numerous host plants and has found that the appendages of the perithecia are not entirely hyaline when mature in all the specimens. In the form on Artemisia, the appendages are recorded as colorless by many authors, but as the result of the studies on about sixty specimens collected at different parts of this country, the writer has found the interesting fact that the perithecia which are embedded in the abundant hairs of the under-surface of the leaves usually have colorless appendages, while those produced on the upper smooth surface have appendages light or deep brown colored toward the base or throughout.

In the forms on *Galium Aparine* and *Serratula coronata,* the appendages remain hyaline for a long time, but finally turn to a brown color.

K. SAWADA regarded the form on Plantago as a new species and described it under the name *Erysiphe Plantaginis* n. sp. He distinguished it from *E. Cichoracearum* by the size of conidia, asci and ascospores and besides by the result of the infection experiments. But the present writer is inclined to recognize it simply as a biological form.

In *Erysiphe Cichoracearum* there are two forms. In one of them the appendages are brown colored from the young stages, and in others they are colorless at first, but finally turn to a brown color when mature.

This species occurs not only on Compositae, but also on many other families, but the writer could not recognize in them any important difference in the morphological characters.

Erysiphe Galeopsidis DC.

(Pl. VIII, fig. 15)

Fl. Fr. VI, p. 108, 1815; DE BARY, Beitr. Morph. Phys. Pilz. I, xiii, p. 49, 1870; SACC. Syll. Fung. I, p. 16, 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 33, 1884; BURR. & EARLE, Ill. Stat. Lab. Nat. Hist. II, p. 404, 1887; ELL. & EVERH. N. Amer. Pyren. p. 13, 1892; JACZEW. Bull. l'Herb. Boiss. IV, p. 731, 1896; OUDEM. Rév. Champ. Pays-Bas, II, p. 95, 1897; MAGNUS, Erysiph. Tirol. p. 17,

1898; SALM. Monogr. Erysiph. p. 204, 1900, Bull. Torr. Bot. Club, XXVII, p. 443, 1900, and XXIX, p. 193, 1902; NEGER, Krypt. Fl. d. Mark Brand. VII, p. 115, 1905; KLIKA, Erysiph. Czechosl. p. 63, 1924; ŠKORIĆ, Erysiph. Croat. p. 45, 1926. (TRACY & GALLOW. Journ. Myc. IV, p. 34, 1888; PAMM. Journ. Myc. IV, p. 37, 1888; GRIFF. Bull. Torr. Bot. Club, XXVI, p. 142, 1899; SALM. Bull. Torr. Bot. Club, XXVII, p. 443, 1900, Ann. Myc. III, p. 249, 1905, and VI, p. 8, 1908; MATSUM. Ind. Plant. Jap. I, p. 141, 1904; SHIRAI, List, p. 32, 1905; RANOJ. Ann. Myc. VIII, p. 356, 1910; IDETA, Jap. Phytopath. p. 205, 1911, and Jap. Phytopath. (Suppl. I), p. 201, 1923; SAWADA, Agric. Exp. Stat. Formosa, Bull. IX, p. 33, 1914; SHIRAI & MIYAKE, List, p. 223, 1917; TOGASHI, Jap. Journ. Bot. II, p. 78, 1924; SHIRAI & HARA, List, p. 132, 1927).

Syn. *Alphitomorpha communis* var. *Labiatarum* WALLR. Berl. Ges. Nat. Freund. Verh. I, p. 31, 1819.

Erysiphe communis FR. Syst. Myc. III, p. 239 (p.p.), 1829.

Erysiphe Chelones SCHWEIN. Syn. Fung. Am. Bor. p. 270, 1834; SACC. Syll. Fung. I, p. 21, 1882.

Erysiphe lamprocarpa MÉRAT, Nouv. Fl. Paris, p. 75 (p.p.), 1837, and Syn. Nouv. Fl. Paris, p. 84 (p.p.), 1837.

Erysibe lamprocarpa LK. in RABENH. Deutschl. Krypt. Fl. I, p. 232 (p.p.), 1844.

Erysiphe Labiatarum LIND, Danish Fung. p. 162, 1913.

Erysibe Galeopsidis DC. in SCHRÖT. COHN's Krypt. Fl. Schles. III, p. 237, 1893. (JAAP, Ann. Myc. IX, p. 333, 1911).

Oidium erysiphoides FR. *Syst. Myc. III, p. 432 (p.p.), 1829;* SACC. Syll. Fung. IV, p. 41 (p.p.), 1886; LIND. in RABENH. Krypt. Fl. Deutschl. VIII, p. 79 (p.p.), 1907.

Oidium Hormini FARN. Svil. e Polim. Nuovo, Microm. Par. VII, p. 5, 1902; SACC. Syll. Fung. XVIII, p. 505, 1906.

Oidium Lamii RABENH. Krypt. Fl. Deutschl. VIII, p. 81, 1907.

Amphigenous, on stems and petioles; mycelium persistent or evanescent, at first forming white thin effused film, and finally turning to a deep brown color; matured conidia in a chain, vacuolate, granulate, subglobose or ellipsoidal, 26.4–37.2 × 12.8–20.4 μ; perithecia gregarious or scattered, 112–161 μ in diameter, globose or depressed-globose; cells 10.8–19.2 × 8.4–12.0 μ; appendages about 17–31 in number, irregular in length, about 2–4 times the diameter of the perithecia, brown colored throughout, evidently 1–5 septate, al-

most always simple, sometimes vaguely branched; asci 5–11 in number, ovate or pyriform, pedicellate, 45.6–72.0 × 21.6–34.8 μ; spores remain immature on the living host.

Hab. On leaves, petioles and stems of *Geranium erianthum* DC. (Chishima-furo). Hokkaido—Kitami.

On *Geranium nepalense* SWEET. (Furoso). Hokkaido—Ishikari.

On *Geranium sibiricum* L. (Ichige-furo). Hokkaido—Kitami, Kushiro.

On *Geranium yezoense* FRANCH. & SAV. (Yezo-furo). Hokkaido—Ishikari.

On *Chelonopsis longipes* MAKINO (Tani-jakoso). Shikoku—Tosa.

On *Chelonopsis moschatus* MIQ. (Jakoso). Hokkaido—Oshima, Shiribeshi.

On *Galeopsis Tetrahit* L. (Chishima-odorikoso). Saghalien—Maoka, Futarayapachi, Ochiai, Alexandrowsk, Nayoshi, Ambetsu, Konuma, Shimizu, Baguntan, Horo, Sakaehama. Hokkaido—Kitami, Kushiro.

On *Lamium album* L. var. *barbatum* FR. & SAV. (Odorikoso). Saghalien—Odomari. Hokkaido—Oshima, Shiribeshi, Ishikari, Kushiro. Honshu—Rikuchu, Musashi, Kozuke, Yamashiro. Kyushu—Higo.

On *Lycopus lucidus* TURCZ. var. *genuinus* HERD. (Shirone). Hokkaido—Ishikari.

On *Plectranthus glaucocalyx* MAXIM. var. *japonicus* MAKINO (Hikiokoshi). Honshu—Rikuchu.

On *Stachys baicalensis* FISCH. var. *hispida* NAKAI (Yezo-inugoma). Hokkaido—Ishikari, Kitami, Tokachi.

On *Stachys baicalensis* FISCH. var. *hispidula* NAKAI (Inugoma). Hokkaido—Ishikari. Honshu—Musashi.

On *Ligularia stenocephala* MATSUM. (Metakarako). Honshu—Mutsu, Shimozuke.

Distrib. All over the world.

Remarks. The ascospores of the present fungus remain immatured *on the living host plants.* SALMON *said that Erysiphe Galeopsidis* differs from *Erysiphe Cichoracearum* by "the lobed haustoria and the non-development of spores on the living host plant". On the other hand, several authors have recorded that two spores are developed in an ascus in the next year and that such a character is restricted to the Labiatae.

Erysiphe Galeopsidis resembles *Erysiphe Cichoracearum* in number of spores, although they are produced in the following year, and also in the fact that conidia are produced in a perfect chain.

Oidium belonging to Erysiphe

Polygoni section.

On *Beta vulgaris* L. var. *Rapacea* C. KOCH. (Sato-daikon). Hokkaido—Ishikari.

On *Chrysosplenium flagelliferum* FR. SCHM. (Tsuru-nekonome). Hokkaido—Ishikari.

On *Agastache rugosa* KUNTZE (Kawamidori). Honshu—Echigo.

On *Agastache rugosa* KUNTZE var. *hypoleuca* KUDO (Kita-kawamidori). Hokkaido—Kushiro.

Cichoracearum section.

On *Elodes japonica* BL. (Mizu-otogiri). Honshu—Echigo.

On *Brunella vulgaris* L. (Utsubo-gusa). Honshu—Kaga.

On *Sesamum indicum* L. (Goma). Honshu—Etchu, Izumo.

Uncinula LÉV.

Mycelium is superficial, thinly effused as a cobweb; haustoria are sent into epidermal cells or sometimes into subepidermal tissues of the host plants, they are globose or subglobose in shape and thin-walled, including granules; matured conidia are produced either solitary or very rarely in a chain, and are smaller than in the Microsphaera, including vacuoles and granules; perithecia are globose or depressed-globose, including several asci; appendages are simple and usually hyaline, frequently colored, and with or without several septa, and the apex is uncinate. This genus includes 23 species in this country. Among them 4 species are new to science.

Key to the species of the genus Uncinula

A. Appendages enlarged at the circinate part.
  1. Ascospores 3–7.
    Appendages straight .... *U. Clintonii* (344)
    Appendages narrower and rarely bent .... *U. Zelkowae* (346)
  2. Ascospores 2 .... *U. clandestina* (347)
B. Appendages not enlarged at the circinate part.
 I. Appendages broad in diameter.
  1. Appendages straight and smooth.
    Appendages enlarged upward .... *U. Delavayi* (349)
    Appendages sometimes divided .... *U. bifurcata* (349)
    Appendages narrowed at the apical part .... *U. australiana* (350)
    Appendages stout, frequently narrowed in the basal part .... *U. Sengokui* (351)
  2. Appendages frequently twisted.
    * Appendages colorless.
      Appendages frequently enlarged upward ... *U. Salmoni* (352)
      Appendages not enlarged upward .... *U. Picrasmae* (353)

* Appendages colored.

Appendages, 126–210 μ in length .... *U. necator* (367)

Appendages longer, 140–238 μ in length .... *U. Actinidiae* (353)

II. Appendages narrow.

1. Appendages straight.

a. Appendages aseptate or uni-septate.

* Appendages colorless or light brown colored at the base.

Appendages 112–126 μ in length .... *U. verniciferae* (355)

Appendages very numerous, 41–117 μ in length .... *U. Salicis* (356)

* Appendages colored throughout .... *U. simulans* (359)

b. Appendages multi-septate.

Circinate part of appendages narrowed and not septate .... *U. curvispora* (360)

Circinate part of appendages rather broad and several septate .... *U. septata* (361)

2. Appendages geniculate or flexuous.

a. Appendages geniculate.

Appendages 112–182 μ (aver. 158.6 μ) in length .... *U. geniculata* (361)

Appendages 119–210 μ (aver. 148.8 μ) in length .... *U. Betulae* (362)

Appendages 154–231 μ (aver. 184 μ) in length .... *U. carpinicola* (363)

b. Appendages flexuous.

Appendages 154–238 μ in length .... *U. Fraxini* (364)

Appendages 112–238 μ in length and uncinate part not narrowed, sometimes angulary bent ...... *U. Miyabei* (365)

Appendages 126–168 μ in length and uncinate part abruptly narrowed .... *U. Mori* (366)

Appendages 84–120 μ in length and usually 10 in number .... *U. Nishidana* (367)

Uncinula Clintonii PECK

(Pl. VIII, figs. 16, 17, 18)

Trans. Albany Inst. VII, p. 216, 1872; SACC. Syll. Fung. I, p. 17, 1882; ELL. & EVERH. N. Amer. Pyren. p. 15, 1892; SALM. Monogr. Erysiph. p. 109, 1900, and Bull. Torr. Bot. Club, XXIX, p. 100, 1902; TAI & WEI, Sinensia, III, p. 103, 1932. (SALM. Bull. Torr. Bot. Club, XXVIII, p. 446, 1900, Ann. Myc. III, p. 252, 1905, and VI, p. 12, 1908; MATSUM. Ind. Pl. Jap. I, p. 178, 1904; P. HENN. in ENGL. Bot. Jahrb. XXXIV, p. 600, 1905; SHIRAI, List, p. 102, 1905; YOSHINAGA, Bot. Mag. Tokyo, XIX, p. 35, 1905; YOSHINO, Bot. Mag. Tokyo, XIX,

p. 206, 1905; IDETA, Jap. Phytopath. p. 214, 1911; SYDOW, Ann. Myc. XI, p. 114, 1913; SHIRAI & MIYAKE, List, p. 675, 1917; SAWADA, Agr. Exp. Stat. Formosa, Bull. XIX, p. 175, 1919; HARA, Dendropath. p. 23, 1923; SHIRAI & HARA, List, p. 402, 1927).

Syn. *Uncinula Kusanoi* SYD. Mem. l'Herb. Boiss. IV, p. 4, 1900; SACC. Syll. Fung. XVI, p. 401, 1902. (NAMBU, Bot. Mag. Tokyo, XVIII, p. 2, 1904; SHIRAI, List, p. 103, 1905; SHIRAI & MIYAKE, List, p. 675, 1917).

Amphigenous, usually hypophyllous; mycelium subpersistent or evanescent, at first forming circumscribed white mycelial patches; perithecia 98–133 μ in diameter, gregarious or scattered, globose; cells 16.8–27.6 $\times$ 9.6–19.2 μ in size; appendages 6–23 in number, straight aseptate or uni-septate near the base, colorless, apex uncinate or circinate and generally wider than the other part, 77–196 μ long; asci 4–6, ovate or oval, with a short stalk, 43.2–63.6 $\times$ 36.0–50.4 μ; spores 4–6, usually 6, elongate-ellipsoidal, granulate, 18.0–31.2 $\times$ 9.6–16.8 μ.

Hab. On leaves of *Aphananthe aspera* PLANCH. (Muku-enoki). Honshu—Rikuchu, Rikuzen, Ugo, Musashi, Echigo, Etchu, Suruga.

On *Celtis sinensis* PERS. (Enoki). Honshu—Rikuchu, Musashi, Kazusa, Hitachi, Echigo, Yamashiro, Bizen, Bitchu. Shikoku—Awa, Iyo, Tosa. Kyushu—Buzen, Higo. Formosa—Daihoku.

On *Tilia japonica* SIMK. (Shinanoki). Hokkaido—Ishikari.

Distrib. Japan (Hokkaido, Honshu, Shikoku, Kyushu and Formosa), China and North America.

Remarks. The species of Uncinula parasitic on Celtis have been very much confused. The species, which have hitherto been published, are *Uncinula Clintonii*, *U. polychaeta*, *U. Shiraiana*, *U. Kusanoi*, *U. parvula* and *U. confusa*. The co-type specimens of *U. Shiraiana* and *U. Kusanoi*, and those of *U. Clintonii* and *U. polychaeta*, are fortunately preserved in our herbarium. *U. Clintonii* is originally the form occurring on Tilia in America, but SALMON has included in this species the fungus on Celtis and Aphananthe which were sent to him from Japan.

Uncinula polychaeta was recorded on Celtis as an American endemic species, but in 1900, SALMON determined as the same species

the form on Celtis from China and also that on *Aphananthe aspera* from Japan (coll. Y. SENGOKU, Oct. 29, 1895, in Tokyo).

Uncinula Shiraiana was the name given by P. HENNINGS to the fungus on *Celtis sinensis* which was sent to him from Japan (coll. S. KUSANO, Oct. 26, 1899, in Bot. Gard. Tokyo).

Uncinula polychaeta and *U. Shiraiana* parasitic on Celtis, as the result of our careful studies, seem to belong to the genus Uncinulopsis (see genus Uncinulopsis), judging from the characters of mycelium and the form of conidia. As to *Uncinula Kusanoi*, in 1900, P. HENNINGS first described it from the specimen on *Celtis sinensis* from Japan (coll. S. KUSANO Oct. 26, 1899, in Meguro, Tokyo). He compared it with *Uncinula confusa*, *U. parvula* and *U. polychaeta*, but said nothing about *U. Clintonii*. A minute examination of the co-type specimens of *Uncinula Kusanoi*, discloses that it entirely coincides with *U. Clintonii*. *Uncinula parvula* is also a fungus from North America, and the number of appendages of a perithecium is 50–160. Up to the present time, this species has not been collected in this country.

As to *Uncinula confusa*, according to the original description of MASSEE, the size of the perithecia is 150–200 μ in diameter. *U. Clintonii* whose perithecia reach to 130 μ in diameter, can easily be distinguished from *U. confusa* in this respect.

Uncinula parasitic on *Zelkowa serrata* (coll. K. MIYABE, Aug. 24, 1889, in Kobe) was included under *Uncinula Clintonii* by SALMON, but the writer is inclined to consider it rather as *Uncinula Zelkowae*.

In the form on *Tilia japonica*, the appendages of the perithecium are longer than those of the form parasitic on Celtis, and they are longer than those of the American type too, but in other characters these forms could not be distinguished from each other.

In the form on *Aphananthe aspera*, the appendages are 6–16 in number, but in other points it coincides with the present species.

Uncinula Zelkowae P. HENN.

(Pl. VIII, fig. 19)

in ENGL. Bot. Jahrb. XXIX, p. 149, 1901; SACC. Syll. Fung. XVI, p. 400, 1902. (SHIRAI, List, p. 104, 1905; SHIRAI & MIYAKE, List, p. 679, 1917; HARA, Dendropath. p. 18, 1923; SHIRAI & HARA, List, p. 403, 1927).

Amphigenous, mycelium evanescent; matured conidia solitary, oblong or cylindrical, granulate, vacuolate, 26.4–37.2 × 10.8–16.8 μ; perithecia scattered, 79.2–124.8 μ in diameter, globose or depressed-globose; cells 16.0–19.2 × 12.0–15.6 μ in size; appendages 14–25 in number, aseptate or very rarely uni-septate at the base, flexuous, 2 or 3 times at the upper half, hyaline or a slightly light brown color at the base, very irregular in length, 69.6–176.0 μ, simple, width at the base 5.6 μ, middle 4.0 μ, apex 8.4 μ, abruptly enlarged at the circinate part; asci 2–5, subglobose or ovate, 51.6–55.2 × 33.6–48.0 μ; spores 3–6, elongate-ellipsoidal or ovate, 19.2–28.8 × 12.0–15.6 μ.

Hab. On leaves of *Zelkowa serrata* MAK. (Keyaki). Honshu—Rikushu, Rikuzen, Hitachi, Echigo, Etchu, Settsu, Inaba.
Distrib. Japan (Honshu).

Remarks. *Uncinula Zelkowae* is an endemic species in this country. It is related to *Uncinula Clintonii* and *U. clandestina*. *U. clandestina* has always two spores in an ascus. Compared with *U. Clintonii*, the appendages of the perithecium of the present species are more or less narrow, straight and irregular in length, especially in the specimen collected in Kobe in which the size of perithecia is very small, 79.2–96 μ and the appendages are narrower and shorter.

Uncinula clandestina (BIV. BERN.) SCHRÖT.

(Pl. VIII, fig. 20)

in COHN's Krypt. Fl. Schles. III, p. 245, 1893; SALM. Monogr. Erysiph. p. 97, 1900, and Bull. Torr. Bot. Club, XXIX, p. 99, 1902; LINDAU, Krypt. d. Mark Brand. p. 133, 1905; ŠKORIĆ, Erysiph Croat. p. 42, 1926; TAI & WAI, Sinensia, III, p. 102, 1932. (SALM. Bull. Torr. Bot. Club, XXVII, p. 446, 1900, and Ann. Myc. III, p. 252, 1905; MATSUM. Ind. Plant. Jap. I, p. 178, 1904; SHIRAI, List, p. 102, 1905; RANOJ. Ann. Myc. VIII, p. 357, 1910; IDETA, Jap. Phytopath. p. 214, 1911, and Jap. Phytopath. (Suppl. I) p. 215, 1923; SAWADA, Agric. Exp. Stat. Formosa, Bull. IX, p. 68, 1914; SHIRAI & MIYAKE, List, p. 675, 1917; HARA, Dendropath. p. 23, 1923; SHIRAI & HARA, List, p. 402, 1927).

Syn. *Erysiphe clandestina* BIV. BERN. Stirp. Rar. Sic. Man. III, p. 20, 1815.

Erysibe adunca LK. var. *ulmorum* LK. in WILLD. Sp. Pl. VI, p. 112, 1824; RABENH. Deutschl. Krypt. Fl. I, p. 236, 1844.

Erysiphe adunca FR. Syst. Myc. III, p. 245, 1829.

Uncinula Bivonae LÉV. Ann. Sci. Nat. III, 15, p. 151, 1851; KICKX, Fl. Crypt. Fland. I, p. 377, 1867; COOKE & PECK, Journ. Bot. I, p. 11, 1872; SACC. Syll. Fung. I, p. 6, 1882; RABENH. Krypt. Fl. Deutschl. I, 2, p. 40, 1884; JACZ. Bull. l'Herb. Boiss. IV, p. 741, 1896; MAGNUS, Erysiph. Tirol. p. 21, 1898. (FUCK. Symb. Myc. p. 80, 1869–1870).

Erysiphe Bivonae TULASNE, Select. Fung. Carp. I, p. 200, 1861.

Uncinula clandestina (BIV. BERN.) SCHRÖT. f. *japonica* P. HENN. in ENGL. Bot. Jahrb. XXIX, p. 149, 1901. (Shirai, List. p. 102, 1905).

Amphigenous, mostly epiphyllous; mycelium persistent, at first forming thin white patches and finally covering the entire upper surface of the leaves; perithecia gregarious or scattered, 77–112 μ in diameter, globose, blackish brown colored; cells 14.4–16.8 × 12.0–14.4 μ in size; appendages 8–30 in number, aseptate, hyaline, becoming broad towards the apex, 69.6–114 μ long, simple, straight, the apex circinate or uncinate; asci 3–4, usually 4, globose or subglobose, rarely short stalked, 40.8–50.4 × 36.0–57.2 μ; spores 2, large, granulate, 21.6–32.4 × 15.6–17.4 μ.

Hab. On leaves of *Ulmus laciniata* MAYR. (Ohyo). Hokkaido—Ishikari, Kushiro.

On *Ulmus parvifolia* JACZ. (Aki-nire). Honshu—Mutsu, Musashi. Kyushu—Higo.

On *Ulmus propinqua* KOIDZ. (Haru-nire). *Hokkaido—Ishikari. Honshu—Musashi.*

Distrib. Japan (Hokkaido, Honshu and Kyushu), Manchuria, China, Europe and Africa.

Remarks. In the present species, the uncinate parts of the appendages are abruptly enlarged and the asci are bi-spored. By these characters it can be distinguished from other related species.

In 1901, the fungus on *Ulmus parvifolia* (coll. S. KUSANO) was recorded as a form of this species by P. HENNINGS. As results of our studies on the co-type specimen of this fungus, the perithecia are found to be 77–97 μ in diameter, appendages of the perithecium to be 8–29 in number and 69.6–91.0 μ long, asci and ascospores to be of a similar size to those of *U. clandestina*. According to this observation, the size of perithecia and length of appendages are more or less smaller and shorter, but in the other important characters, the form on *U. parvifolia* could not be distinguished from the present species.

Uncinula Delavayi PAT.

(Pl. VIII, fig. 21)

Journn. Bot. II, p. 217, 1888; SACC. Syll. Fung. IX, p. 367, 1891; SALM. Monogr. Erysiph. p. 118, 1900. (SALM. Ann. Myc. III, p. 252, 1905, and VI, p. 12, 1908; IDETA, Jap. Phytopath. p. 215, 1911; SYD. Ann. Myc. XII, p. 161, 1914; SHIRAI & MIYAKE, List, p. 675, 1917; HARA, Dendropath. p. 24, 1923; SHIRAI & HARA, List, p. 402, 1927).

Amphigenous, mycelium persistent on the upper surface of the leaves and evanescent on the under; perithecia gregarious or subgregarious, 112–161 μ in diameter, depressed-globose; cells 13.2–19.2 μ wide; appendages 9–15, more or less enlarged towards the apex, 1- or 2-septate, hyaline, straight, granulate in the tip, 126–157 μ long, usually about 150 μ, apex circinate; asci 6–9 in number, ovate, with short stalk, 43.2–60.0 × 33.6–43.2 μ; spores 6–8, ellipsoidal or elongate-ellipsoidal, 17.6–18.0 × 10.8–12.0 μ.

Hab. On leaves of *Cedrela sinensis* JUSS. (Chanchin). Honshu—Mutsu, Rikuchu, Musashi, Echigo.

Distrib. Japan (Honshu) and China.

Remarks. In this country, the first record of the present species on *Cedrela sinensis* was by SALMON. The appendages of the perithecium are enlarged toward the tip, they are much wider than in the case of the other species of Uncinula and they are perfectly smooth and stout. This species is related to *Uncinula australiana* and *U. Sengokui*, but in the former, the circinate parts of the appendages are narrow, and in the latter, the appendages are frequently flexuous.

Uncinula bifurcata HOMMA sp. nov.

(Pl. VIII, fig. 22)

Amphigena, plerumque epiphylla; mycelio persistente, albo, demum griseo; peritheciis sparsis, globosis v. globoso-depressis, 88–126 μ. diam., cellulis 15.6–19.2 × 14.4–16.8; appendicibus 9–14, simplicibus v. bifurcatis, 102–154 μ. longis, rectis v. curvatis, continuis v. 1-septatis, deorsum brunneis, apice uncinatis, tenue tunicatis; ascis 5–8 in quoque perithecio, ellipsoideis v. ovatis, brevissime pedicellatis, 48.0–70.8 × 28.8–40.8, 3–4-sporis; sporidiis ellipsoideis v. oblongo-ovatis, 12.8–18.0 × 8.4–12.0.

Hab. On leaves of *Quercus serrata* THUNB. (Konara) Honshu—Prov. *Echigo; Mt. Ninoji* (Oct. 10, 1924, Y. HOMMA, type).
Distrib. Japan (Honshu).

Remarks. Up to the present time, Uncinula known to be parasitic on Quercus has been restricted to *U. septata*. *Uncinula septata* can easily be distinguished from the present species by its many septate appendages. The present species appears on both surfaces of the leaves and at first the mycelium is white, gradually becoming a gray color just as in the case *Cystotheca lanestris*. The characteristic point of the appendages is in their dichotomous branching at the base, while in the other characters, they are nearly similar to *Uncinula Delavayi* and *U. Sengokui*. Compared with *U. Delavayi*, the perithecia in the present species are smaller, and the septa of the appendages are less, besides being brown-colored at the base. Compared with *Uncinula Sengokui*, the appendages of the perithecium in the species under consideration are less in number.

Uncinula australiana MCALPINE

(Pl. VIII, fig. 23)

Journ. Linn. Soc. N. S. Wales, XXIV, p. 302, 1899; SALM. Monogr. Erysiph. p. 118, 1900; SACC. Syll. Fung. XXII, p. 21, 1910; TAI & WEI, Sinensia, III, p. 101, 1932. (SALM. Bull. Torr. Bot. Club, XXVII, p. 446, 1900; MATSUM. Ind. Pl. Jap. 1, p. 178, 1904; SHIRAI, List, p. 102, 1905; IDETA, Jap. Phytopath. p. 215, 1911; SHIRAI & MIYAKE, List, p. 675, 1917; HARA, Dendropath. p. 22, 1923; SHIRAI & HARA, List, p. 402, 1927).

Amphigenous, mycelium persistent, at first forming white circular patches on the leaves; matured conidia solitary, ellipsoidal, vacuolate, 24.0–34.5 × 15.0–19.0 μ; perithecia 112–140 μ in diameter, globose or depressed-globose; cells 12.0–14.4 μ in width; appendages 13–17 in number, usually uni-septate, amber brown-colored at the base, gradually becoming narrower toward the apex, especially narrow at the circinate part; asci 4 or 5 in number, ovate or subglobose, with or without short stalk, 50.4–57.6 × 40.8–50.4 μ; spores 7 or 8, usually 8, ellipsoidal, 13.2–20.4 × 9.6–15.6 μ.

Hab. On leaves of *Lagerstroemia indica* L. (Sarusuberi). Honshu—Rikuzen, Musashi, Kozuke, Suruga, Yamashiro. Shikoku—Iyo. Kyushu—Higo. Formosa—*Daihoku*.

Distrib. Japan (Honshu, Shikoku, Kyushu and Formosa), China and Australia.

Remarks. In the present species, the appendages of the perithecium are smooth, deep brown-colored under the septum and narrowed in the circinate part.

Uncinula Sengokui SALM.

(Pl. VIII, fig. 24)

Monogr. Erysiph. p. 120, 1900, and Bull. Torr. Bot. Club, XXIX, p. 647, 1902; SACC. Syll. Fung. XVI, p. 399, 1902. (SALM. Bull. Torr. Bot. Club, XXVII, p. 447, 1900, Ann. Myc. III, p. 253, 1905, and VI, p. 12, 1908; MATSUM. Ind. Plant. Jap. I, p. 179, 1904; SHIRAI, List, p. 103, 1905; IDETA, Jap. Phytopath. p. 215, 1911; SHIRAI & MIYAKE, List, p. 679, 1917; HARA, Dendropath. p. 23, 1923; SHIRAI & HARA, List, p. 403, 1927).

Amphigenous, mycelium persistent on the upper surface of the leaf, evanescent on the under surface, at first forming white roundish mycelial patches; matured conidia produced in a chain, ellipsoidal, granulate, including well developed fibrosin bodies, 24.0–27.6 × 13.6–17.6 μ; perithecia scattered, 105–133 μ in diameter, globose or depressed-globose; cells various in form and size, 12.0–18.0 × 10.8–16.8 μ in size; appendages 11–23 in number, straight, broad, stout, more or less light colored at the base, sometimes hyaline, aseptate, rarely 1-septate, 112–154 μ in length, apex uncinate, frequently a little expanded at the first part of the coil; asci broadly ovate or oval, with a stalk, hyaline, thin-walled, granulate, 4–7 in number, 48.0–64.8 × 31.2–43.2 μ; spores 4–6 in number, usually 5, oval, ellipsoidal or oblong, granulate, 18.0–21.6 × 9.6–13.2 μ.

Hab. On leaves of *Celastrus articulata* THUNB. (Tsuru-umemotogi). Hokkaido—Iburi, Ishikari. Honshu—Musashi.

Distrib. Japan (Hokkaido and Honshu) and Manchuria.

Remarks. The present fungus was sent to SALMON (in 1900) from MIYABE, together with many other Japanese specimens. SALMON described it as a new species after the name of the collector. This species is distinguished from others by the form of the appendages, which are stout, straight, broad, hyaline or slightly pale brown colored at the base and perfectly uncinate at the apex. At the base of the uncinate apex, a swollen part is frequently observed.

Uncinula Salmoni SYDOW
(Pl. IX, fig. 1)

Ann. Myc. XI, p. 114, 1913; SACC. Syll. Fung. XXIV, p. 225, 1928. (SHIRAI & MIYAKE, List, p. 679, 1917; HARA, Dendropath. p. 23, 1923; IDETA, Jap. Phytopath. (Suppl. I), p. 215, 1923; SHIRAI & HARA, List, p. 403, 1927).

Syn. *Uncinula Sengokui* SALM. forma SALM. Ann. Myc. III, p. 253, 1905.

Amphigenous, mycelium subpersistent or evanescent; perithecia gregarious or scattered, globose, 90–126 μ in diameter; cells 13.2–16.8 × 9.6–14.4 μ in size; appendages 13–22 in number, yellowish brown colored at the base, aseptate or 1-septate, 91–140 μ in length, generally enlarged upward, very irregular in width, apex uncinate or helicoid; asci 4–6 in number, usually 5, globose, short stalked, 43.2–49.2 × 30.0–42.0 μ; spores ellipsoidal or oblong, 6–7 in number, 16.8–20.4 × 10.8–13.2 μ.

Hab. On leaves of *Fraxinus japonica* BL. (Toneriko). Hokkaido—Ishikari. Honshu—Musashi, Echigo. Kyushu—Bungo.

On *Fraxinus longicuspis* SIEB. & ZUCC. (Koba-no-toneriko). Honshu—Rikuchu.

On *Fraxinus mandschurica* RUPR. (Yachidamo). Hokkaido—Hidaka.

On *Fraxinus ornus* L. Honshu—Musashi.

On *Fraxinus Sieboldiana* BL. (Aodamo). Honshu—Etchu.

On *Fraxinus Sieboldiana* BL. var. *pubescens* KOIDZ. (Arage-aodamo). Honshu—Musashi.

Distrib. Japan (Hokkaido, Honshu and Kyushu) and Manchuria.

Remarks. In 1905, SALMON considered the present species as a form of *Uncinula Sengokui*, based on the fungus collected in Tokyo, Nov. 6, 1901, by K. YOSHINO. In 1913, SYDOW separated it from *Uncinula Sengokui*, and recognized it as a new species. It has a close affinity to *U. Sengokui*, but is distinguished from the latter by the perithecia being smaller, the appendages being irregular in width or frequently enlarged upward, and the asci being fewer in number as well as larger in size.

On the other hand, in *U. Fraxini*, the perithecia are smaller in diameter, and the appendages are delicate, narrowed throughout and longer than in *U. Salmoni*.

In the form on *Fraxinus Sieboldiana* var. *pubescens*, the appendages are longer than in the case on other host plants, being 98–140 μ, usually 112–126 μ in length.

Uncinula Picrasmae HOMMA, sp. nov.

(Pl. IX, fig. 2)

Amphigena; mycelio persistente; peritheciis sparsis v. subgregariis, globosis v. globoso-depressis, 96–120 μ. diam., cellulis 12.0–14.4 × 8.4–10.8; appendicibus 14–25, continuis v. 1- 2- septatis, deorsum fulvis, 147–182 μ. longis, rectis v. lenissime curvulis, superne abrupte flexis, apice uncinatis v. helicoideis; ascis 4–6 in quoque perithecio, subglobosis, brevissime pedicellatis 45.6–62.4 × 38.4–50.4, 6–8-sporis; sporidiis ellipsoideis, 15.4–21.6 × 8.4–12.0.

Hab. On leaves of *Picrasma quassioides* BENN. (Nigaki). Hokkaido—Prov. Iburi: Tomakomai (Oct. 17, 1904, K. MIYABE & J. HANZAWA). Prov. Ishikari: Nopporo (Oct. 2, 1921, K. TOGASHI; Sept. 14, 1922, Y. HOMMA, type; Oct. 12, 1923, H. TAKASUGI).

Honshu—Prov. Musashi: Himonya, Tokyo (Apr. 18, 1923, K. KITAJIMA).

Distrib. Japan (Hokkaido and Honshu).

Remarks. The present species seems to take an intermediate place between *Uncinula Salmoni* and *U. Actinidiae*. The appendages of this species are not enlarged upward and are longer than in *U. Salmoni*, while from *U. Actinidiae* it can easily be distinguished by the lighter colored appendages. It is considered from the above characters, that the present fungus should be treated as a new species.

Uncinula Actinidiae MIYABE

(Pl. IX, fig. 3)

in SALMON, Monogr. Erysiph. p. 101, (nomen nudum) 1900.

Syn. *Uncinula necator* (SCHWEIN.) BURR. in SALM. Monogr. Erysiph. p. 99 (p.p.), 1900. (SALM. Bull. Torr. Bot. Club, XXVII, p. 447, 1900, and Ann. Myc. VI, p. 12, 1908; SHIRAI, List, p. 103 (p.p.), 1905; SHIRAI & MIYAKE, List, p. 677, 1917).

Uncinula necator (SCHWEIN.) BURR. var. *Actinidiae* HARA, Journ. Forest. Assoc. Jap. No. 392, p. 63, 1915; TANAKA, Mycolog. XI, p. 81, 1919; SACC. Syll. Fung. XXIV, p. 224, 1928. (HARA, Dendropath. p. 23, 1923; SHIRAI & HARA, List, p. 403, 1927).

Amphigenous, mycelium persistent or evanescent, usually forming thin effused film, and causing an atrophy of young leaves; matured conidia produced in a chain or solitary, ellipsoidal, vacuolate, granulate, including well-developed fibrosin bodies, 19.2–42.0 × 14.4–18.0 μ; perithecia gregarious or scattered, 91–112 μ in diameter, globose or depressed-globose; cells 16.8–19.2 × 14.4–16.8 μ in size; appendages 7–13 in number, usually 9, 1-septate, brown colored for more than half their length, 140–238 μ long, simple, sometimes dichotomously branched at the upper half, apex irregular in form, broad or narrowed, loosely helicoid or uncinate, more or less widened toward the base; asci 4, very rarely 3, globose or subglobose, with short stalk, 50.4–57.6 × 32.4–43.2 μ; spores 7 or 8 in number, elongate-ellipsoidal, 13.4–16.8 × 9.6–10.4 μ.

Hab. On leaves and stems of *Actinidia arguta* PLANCH. (Kokuwa). Hokkaido—Ishikari. Honshu—Musashi.

On *Actinidia Kolomicta* MAXIM. (Miyama-matatabi). Hokkaido—Iburi, Ishikari. Honshu—Musashi.

On *Actinidia polygama* MAXIM. (Matatabi). Hokkaido—Shiribeshi, Ishikari, Hidaka. Honshu—Rikuchu, Rikuzen, Inaba.

Distrib. Japan (Hokkaido and Honshu).

Remarks. In 1900, SALMON made the following remarks in regard to this species; "the occurrence of *Uncinula necator* on species of Actinidia—a genus of plants belonging to Ternstroemiaceae, an order in no way related to Vitaceae—is very interesting, not only because the vine mildew has hitherto been supposed to be confined to vines, but also for the evidence it gives on the question, mentioned below, of the native country of *U. necator*. Professor MIYABE sent me numerous specimens of this form from Japan as *Uncinula Actinidiae* MIYABE mss., but on examination the specimens proved to agree well with certain forms of *U. necator* from America". The present writer made a careful study on the specimens of *U. necator* parasitic on cultivated Vitis from the U. S. A. which had been sent to Prof. MIYABE by Prof. SALMON. These two fungi coincide in the character that their appendages are dark brown colored in the lower half, but in *U. necator*, the appendages are longer and have several septa, the outer wall-cells of the perithecium are very evident, and the spores are rather larger. The appendages of the perithecium of *U. Actinidiae* are frequently dichotomously divided in the upper half. From these characters, the present writer has considered the present fungus as a new species.

In the form which was collected by the author, in the Bot. Gard. Sapporo, Oct. 17, 1923, the appendages are exceedingly irregular in form, here and there producing short or long branches while the apices are almost not uncinate and very rarely falcate. But among them was found a small number having the normal form of *U. Actinidiae* on the same leaves. This material seems to be the result of abnormal formation caused by environmental factors.

Uncinula verniciferae P. HENN.

(Pl. IX, fig. 4)

in ENGL. Bot. Jahrb. XXIX, p. 149, 1901; SACC. Syll. Fung. XVI, p. 399, 1902; SALM. Bull. Torr. Bot. Club, XXIX, p. 101, and p. 648, 1902, and Ann. Myc. III, p. 243, 1905; TAI & WEI, Sinensia, III, p. 114, 1932. (MATSUM. Ind. Plant. Jap. I, p. 179, 1904; SHIRAI, List, p. 104, 1905; YOSHINO, Bot. Mag. Tokyo, XIX, p. 207, 1905; SALM. Ann. Myc. III, p. 253, 1905, and VI, p. 13, 1908; IDETA, Jap. Phytopath. p. 210, 1911; SHIRAI & MIYAKE, List, p. 697, 1917; HARA, Dendropath. p. 17, 1923; SHIRAI & HARA, List, p. 403, 1927; SAWADA, Depart. Agr. Govern. Res. Inst. Formosa, LXI, p. 28, 1933).

Amphigenous, also on fruits, mycelium subpersistent on the leaves, persistent on the fruits, forming thin effused film; perithecia gregarious, globose-depressed, brownish black colored, 112–126 μ in diameter; cells obscure, 12.0–15.6 μ wide; appendages 11–23 in number, commonly aseptate or rarely 1-septate, hyaline or more or less pale brown colored toward the base, 84–112 μ in length, apex simple, narrowed, uncinate or helicoid; asci usually 4, broadly ovate, 45.6–48.0 × 38.4–45.6 μ; spores elongate-ellipsoidal or ovate, 18.4–20.4 × 12.0–14.4 μ.

Hab. On leaves and fruits of *Rhus japonica* L. (Nurude). Honshu—Musashi.

On *Rhus succedanea* L. (Hazenoki). Honshu—Musashi, Izumo, Shikoku—Iyo, Tosa. Kyushu—Higo.

On *Rhus sylvestris* SIEB. & ZUCC. (Yamahaze). Honshu—Musashi.

On *Rhus Toxicodendron* L. var. *vulgaris* PURSH. f. *radicans* ENGL. (Tsuta-urushi). Hokkaido—Ishikari.

On *Rhus trichocarpa* MIQ. (Yama-urushi). Honshu—Rikuchu.

On *Rhus vernicifera* DC. (Urushi). Honshu—Rikuchu, Musashi, Hitachi, Echigo, Ise, Izumo.

Distrib. Japan (Hokkaido, Honshu, Shikoku, Kyushu and Formosa) and China.

Remarks. In 1901, P. HENNINGS described the present species from a specimen on *Rhus vernicifera* which was collected in Tokyo, Bot. Gard. by KUSANO. The writer fortunately could examine the co-type specimen which was sent to Prof. Miyabe from Prof. Kusano. Compared with *U. geniculata*, the appendages in this species are gradually narrowed upwards, straight and not geniculate.

Uncinula Salicis (DC.) WINT.

(Pl. IX, figs. 5, 6, 7)

in RABENH. Krypt. Fl. Deutschl. I, 2, p. 40, 1884; BURR. & EARLE, Bull. Ill. Stat. Lab. Nat. Hist. II, p. 410, 1887; ELL. & EVERH. N. Amer. Pyren. p. 19, 1892; SCHRÖT, in COHN's Krypt. Fl. Schles. III, p. 245, 1893; JACZEW. Bull. l'Herb. Boiss. IV, p. 742, 1896; OUDEM. Rév. Champ. Pays-Bas, p. 87, 1897; MAGNUS, Erysiph. Tirol. p. 20, 1898; SALM. Monogr. Erysiph. p. 81, 1900, and Bull. Torr. Bot. Club, XXIX, p. 96, 1902; NEGER, Krypt. d. Mark Brand. VII, p. 130, 1905; KLIKA, Erysiph. Czechosl. p. 48, 1924; JØRST. Erysiph. Norway, p. 99, 1925; ŠKORIĆ, Erysiph. Croat. p. 43, 1926; TAI & WEI, Sinensia, III, p. 110, 1932. (TRACY & GALLOW. Journ. Myc. IV, p. 35, 1888; PAMM. Journ. Myc. IV, p. 38, 1888; GRIFF., Bull. Torr. Bot. Club, XXVI, p. 144, 1899; SALM. Bull. Torr. Bot. Club, XXVII, p. 447, 1900, Ann. Myc. III, p. 253, 1905, and VI, p. 12, 1908; P. HENN. in ENGL. Bot. Jahrb. XXIX, p. 149, 1901; MATSUM. Ind. Plant. Jap. I, p. 178, 1904; SHIRAI, List, p. 103, 1905; LAWR. Journ. Myc. XI, p. 108, 1905; SYD. Ann. Myc. XI, p. 114, 1913; RANOJ. Ann. Myc. VIII, p. 357, 1910; JAAP, Ann. Myc. IX, p. 333, 1911; IDETA, Jap. Phytopath. p. 214, 1911; SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 66, 1914; SHIRAI & MIYAKE, List, p. 677, 1917; HARA, Dendropath. p. 15, 1923; TOGASHI, Jap. Journ. Bot. II, p. 78, 1924; SHIRAI & HARA, List, p. 403, 1927).

Syn. *Erysiphe salicis* DC. Fl. Fr. II, p. 273, 1805; MÈRAT, Nouv. Fl. Paris, p. 74, 1837, and Syn. Nouv. Fl. Paris, p. 83, 1837; TULASNE, Selecta Fung. Carpolog. I, p. 198, 1861.

Erysiphe adunca (not LK.) MÉRAT, Nouv. Fl. Paris, p. 75 (p.p.), 1837, and Syn. Nouv. Fl. Paris, p. 84 (p.p.), 1837.

Erysiphe populi DC. in DE BARY, Beitr. Morph. Phys. Pilz. I, xiii, p. 52, 1870.

Erysiphe adunca vars. *Populi* et *salicis* FR. Syst. Myc. III, p. 245, 1892.

Uncinula adunca LÉV. Ann. Sci. Nat. III, 15, p. 151, 1851; KICKX, Fl. Crypt. Fland. I, p. 377, 1867; COOKE, Handb. Brit. Fung. II, p. 646, 1871; COOKE & PECK, Journ. Bot. I, p. 12, 1872, and I, p. 170, 1872; QUÉL. Champ. Jur. Vosg. p. 533, 1875; SACC. Syll. Fung. I, p. 7, 1882; LIND, Danish Fung. p. 164, 1913. (FUCK. Symb. Myc. p. 80, 1869–70).

Uncinula heliciformis E. G. HOWE, Bull. Torr. Bot. Club, V, p. 4, 1874; SACC. Syll. Fung. IX, p. 367, 1891.

Erysiphe Populi PAT. Journ. d. Bot. II, p. 217, 1888; SACC. Syll. Fung. IX, p. 370, 1891.

Amphigenous, mostly hypophyllous, mycelium persistent or evanescent, usually thinly effused or forming circular patches; matured conidia solitary, ellipsoidal, granulate, vacuolate, 27.6–30.0 × 16.8–18.0 μ; perithecia globose or depressed-globose, densely gregarious or scattered, 126–210 μ in diameter; cells 10.8–16.2 μ in width; appendages 41–117 in number, aseptate, simple, more or less curved throughout, hyaline, apex uncinate, 64.8–308 μ in length; asci 5–12 in number, subglobose or elongate-ellipsoidal, with a stalk, hyaline, 43.2–86.4 × 31.2–60.0 μ; spores 4–7 in number, ovoid or ellipsoidal, 19.2–28.8 × 9.0–16.8 μ.

Hab. On leaves of *Populus Maximowiczii* A. HENRY (Doro-yanagi). Hokkaido—Ishikari.

On *Populus Sieboldii* MIQ. (Yamanarashi). Hokkaido—Kitami, Kushiro. Honshu—Rikuchu.

On *Salix Bakko* KIMURA (Bakko-yanagi). Hokkaido—Ishikari. Honshu—Echigo.

On *Salix Gilgiana* SEEMEN (Kawa-yanagi). Honshu—Musashi.

On *Salix gracilistyla* MIQ. (Neko-yanagi). Honshu—Rikuchu, Musashi, Echigo, Echizen. Shikoku—Tosa.

On *Salix Hultenii* FLODERS var. *angustifolia* KIMURA (Yezo-no-bakko-yanagi). Hokkaido—Shiribeshi, Iburi, Ishikari.

On *Salix integra* THUNB. (Inu-koriyanagi). Honshu—Rikuchu, Musashi.

On *Salix Lackschewitziana* TOEPFFER (Yezo-yanagi). Hokkaido—Ishikari.

On *Salix purpurea* L. (Koriyanagi). Honshu—Musashi, Hitachi.

On *Salix sachalinensis* FR. SCHM. (Nagaba-yanagi). Hokkaido—Iburi, Ishikari.

On *Salix Sieboldiana* BLUME (Yama-yanagi). Kyushu—Higo.

On *Toisusu Urbaniana* KIMURA (Ohba-yanagi). Honshu—Rikuchu, Etchu.

Distrib. Widely distributed throughout the world.

Remarks. Up to the present time, Salix, Populus and Betul have been known as the host plants of *Uncinula Salicis*. After careful examination of the materials at hand, the writer found tw groups in the forms of *U. Salicis* on Salix. In one of them which i found on *Salix Hultenii* and *Toisusu Urbaniana*, the perithecia ar larger, 140–210 μ in diameter, and the appendages are more numerou and shorter, about 73–117 in number and 113 μ in length. In th other form which is produced on *Salix purpurea*, *S. integra*, *S. Gil giana*, *S. gracilistyla*, *S. sachalinensis* and *S. Lackschewitziana*, th perithecia are smaller, 126–154 μ in diameter, and the appendages ar fewer and rather longer, about 41–67 in number and 126–154 μ i length. The characters of the leaves of the host plants are nearl alike in each group; in the former group, the leaves are larger an broader, and in the latter, they are narrowed and elongated. A first, it appeared that *U. Salicis* might be divided into two species but in other characters they entirely coincide, namely the appendage are hyaline, smooth, more or less curved throughout, and with a uncinate apex, and the asci and ascospores are similar in size. These two forms are too difficult to be divided.

Uncinula Salicis is a very common powdery mildew on willow and is widely spread in this country. In the form on *Salix Hulteni* and *Toisusu Urbaniana*, the mycelium is amphigenous, on *S. gracili styla* and *S. Lackschewitziana* it is epiphyllous, while on other host it is hypophyllous. In the amphigenous group, the mycelium i densely persistent on the upper surface of the leaves and on the lower surface evanescent, even at the time when the perithecia ar produced. The perithecia turn upside down when matured, especial ly on the under surface of the leaf, while on the upper side thi phenomenon very rarely occurs.

In 1900, SALMON remarked, "LÉVEILLE, WINTER, JACZEWSKI SACCARDO and other authors have recorded *U. Salicis* as growing on Betula, but I have not been able to find specimens on this host plant in any herbarium. It may be that perithecia (without appendages) of *Phyllactinia corylea*—species which occurs commonly on Betula—have been mistaken for immature examples of the present species". *Phyllactinia corylea* parasitic on Betula is a very common powdery mildew in this country too, but among the specimens which have been gathered for the present work, we found a fine Uncinula

This form seems at first sight to be near to *U. Salicis*, but it could not be included in it because the appendages are frequently geniculate.

In the form on *Populus Maximowiczii*, the appendages are 98–154 μ in length. In the form on *Populus Sieboldii* (Prov. Rikuchu: Samurai-hara, Oct. 17, 1910, G. YAMADA), the appendages are longer, 182–210 μ. These two forms could not be distinguished from *U. Salicis* although the appendages are longer and more or less flexuous. The form on the latter host plant which was collected in Abashiri, Prov. Kitami, Nov. 1894, by J. Tanaka, has the longest appendages, 210–308 μ in length becoming narrowed upwards, the apices are slightly circinate, and very rarely irregularly branched at the upper half while the asci are more or less larger in size. The writer takes this material to be of an abnormal form.

Uncinula simulans SALM.

(*Pl. IX, fig. 8*)

Ann. Myc. VI, p. 2, 1908; SACC. Syll. Fung. XXII, p. 21, 1910; TAI & WEI, Sinensia, III, p. 112, 1932. (SALM. Ann. Myc. VI, p. 12, 1908; SHIRAI & MIYAKE, List, p. 679, 1917; SHIRAI & HARA, List, p. 403, 1927).

Amphigenous, mycelium evanescent; perithecia scattered, depressed-globose or lenticular, 96–126 μ in diameter; cells nearly black colored, 9.0–12.0 μ wide; appendages 13–25 in number, usually 16, aseptate or 1-septate, conspicuously dark brown colored from the base to the apex, thick-walled throughout, 105–175 μ long, narrowed upward, simple or very rarely branched (1 or 2 in a perithecium), straight or bent at $\frac{1}{3}$ of the length, apex more or less light-colored, uncinate or helicoid; asci 5–7, usually 7, subglobose or broadly ovate, with a short stalk, 50.0–60.0 × 33.6–45.6 μ; spores ellipsoidal, elongate-ellipsoidal or oblong, 16.0–32.4 × 9.6–11.4 μ.

Hab. On leaves of *Rosa multiflora* THUNB. (Nobara). Honshu—Rikuchu, Shimozuke.

Distrib. Japan (Honshu) and China.

Remarks. In 1908, SALMON described the present fungus as a new species of Uncinula which was found parasitic on *Rosa multiflora* collected in Morioka, Sept. 5, 1906, and Oct. 20, 1907, by

OKUMURA. The dark brown colored appendages of the perithecium are the characteristic of the species.

Uncinula septata and *U. curvispora* resemble this species in respect to the colored appendages, but the appendages of those two species have many septa. In *Uncinula simulans* the appendages are usually aseptate or rarely uniseptate and few in number and the perithecia are smaller in size.

Uncinula curvispora HARA

(Pl. IX, fig. 9)

in TANAKA, Mycolog. XI, p. 80, 1919; HARA, Dendropath. p. 21, 1923; SACC. Syll. Fung. XXIV, p. 224, 1928. (SHIRAI & HARA, List, p. 402, 1927).

Syn. *Uncinula septata* SALM. var. *curvispora* HARA, Journ. Forest. Assoc. Jap. No. 392, p. 62, 1915.

Amphigenous, mostly hypophyllous; mycelium evanescent, forming thin effused film; perithecia depressed-globose or lenticular, large, 168–203 μ in diameter; cells 7.2–11.4 × 6.0–6.4 μ; appendages very numerous (about 247), arising from the upper part of the perithecium, 40.8–146.4 μ long, simple, 5–8 septate, brown-colored below the 1st or 3rd septum, gradually narrowed upwards, more or less curved, apex simple, narrow, delicate, circinate or helicoid; asci 10–13, ellipsoidal or oblong, with a short stalk, hyaline, 46.8–55.2 × 26.4–40.8 μ; spores usually immature on the living host plant, "spores ovate or ellipsoidal, yellowish colored, granulate, 28–35 × 12–15 μ, rarely 45–18 μ". (acc. to K. Hara).

Hab. On leaves of *Fagus japonica* MAXIM. (Inubuna). Honshu—Mino.
Distrib. Japan (Honshu).

Remarks. In the genus Uncinula, up to this time the only species has been *U. septata,* which has numerous septa. In 1915, HARA first described a new variety (var. *curvispora*) of *Uncinula septata,* which was afterward in 1919, raised to specific rank.

The appendages of the present fungus are gradually narrowed upward, even to the circinate part. In *Uncinula septata,* the appendages are enlarged upward and have septa from the circinate apex to the base, but in *U. curvispora,* the septa are never produced in the circinate part.

Uncinula septata SALMON

(Pl. IX, fig. 10)

Journ. Bot. XXXVII, p. 427, 1900, and Bull. Torr. Bot. Club, XXIX, p. 102, 1902; SACC. Syll. Fung. XVI, p. 400 and p. 1123, 1902, and XVII, p. 524, 1905; TAI & WEI, Sinensia, III, p. 111, 1932. (MATSUM. Ind. Plant. Jap. I, p. 179, 1904; SALM. Ann. Myc. III, p. 253, 1905, and VI, p. 12, 1908; SHIRAI, List, p. 103, 1905; NAMBU, Bot. Mag. Tokyo, XX, p. 252, 1906; IDETA, Jap. Phytopath. p. 215, 1911; SHIRAI & MIYAKE, List, p. 679, 1917; HARA, Dendropath. p. 19, 1923; SHIRAI & HARA, List, p. 403, 1927).

Hypophyllous, mycelium subpersistent or evanescent; perithecia depressed-globose or lenticular, large, 140–231 μ in diameter; cells 7.8–12.0 × 7.2–9.2 μ in size; appendages numerous, about 168, arising from the upper part of the perithecium, 84.0–105.6 μ in length, colorless, 6–11-septate, narrowed upward, but at uncinate part becoming thickened and septate, thin-walled from the apex to the base, apex simple, uncinate; asci 13–14, ellipsoidal or elongate-ellipsoidal, with a short stalk, hyaline, 43.2–55.2 × 26.4–31.2 μ; spores mostly immature on the living host leaves.

Hab. On leaves of *Quercus serrata* THUNB. (Konara). Honshu—Musashi, Hitachi, Kozuke.

Distrib. Japan (Honshu).

Remarks. The most important characters of the present species are the large size of the perithecium and the septate appendages, whose septa are formed even in the thick uncinate part.

Uncinula geniculata GERARD

(Pl. IX, fig. 11)

Bull. Torr. Bot. Club, IV, p. 48, 1873; ELL. & EVERH. N. Amer. Pyren. p. 19, 1892; SACC. Syll. Fung. I, p. 8, 1882; PAMM. Journ. Myc. IV, p. 37, 1888; SALM. Monogr. Erysiph. p. 111, 1900. (SALM. Ann. Myc. III, p. 252, 1905; Ideta, Jap. Phytopath. p. 215, 1911; SHIRAI & MIYAKE, List, p. 675, 1917; HARA, Dendropath. p. 24, 1923; SHIRAI & HARA, List, p. 402, 1927).

Amphigenous, mostly epiphyllous, mycelium evanescent; perithecia scattered, 102–126 μ in diameter, globose or depressed-globose;

cells 14.4–15.6 × 9.6–12.0 μ in size; appendages 23–36 in number, hyaline, aseptate, smooth, simple, delicate, narrowed upwards, especially so in circinate part, curved or bent at about half their length; asci 5–9, ellipsoidal or broadly ovate, with a short stalk, 48.0–55.2 × 34.4–46.4 μ; spores 5 or 6, ellipsoidal, oblong or ovate, 15.6–21.6 × 9.6–14.4 μ.

Hab. On leaves of *Styrax Obassia* SIEB. & ZUCC. (Hakuumboku). Honshu—Rikuchu, Musashi.

Distrib. Japan (Honshu) and North America.

Remarks. *Uncinula geniculata* has not yet been found on Morus in this country. In 1905, the form on *Styrax Obassia* was included under this species by SALMON.

The appendages of this species are abruptly geniculate at about half their length, which character is found in 2 or 3 appendages in a perithecium. They are delicate, narrow, gradually narrowed upward, straight or more or less curved; and the ascospores are 6 in number in an ascus.

Uncinula Betulae HOMMA, sp. nov.

(Pl. IX, fig. 12)

Syn. *Uncinula Salicis* (DC.) SYD. Ann. Myc. VII, p. 170, 1909.

Amphigena; mycelio epiphyllo tenui, effuso subpersistente; mycelio hypophyllo evanido; peritheciis sparsis, globosis v. globoso-depressis, 84–126 μ. diam., cellulis parvis, 12.0–14.4 × 9.6–10.8; appendicibus 22–38, tenuibus, interdum flexuosis, geniculatis, hyalinis, simplicibus, 119–210 μ. longis, continuis, apice circinatis; ascis 6–12 in quoque perithecio, pedicellatis, 40.8–55.2 × 25.2–38.4, 6–8-sporis; sporidiis oblongis v. oblongo-ellipsoideis, 16.8–18.0 × 9.6–10.8.

Hab. On leaves of *Betula Ermanii* CHAM. var. *subcordata* KOIDZ (Akakamba)

Honshu—Prov. Shinano: Mt. Akaishi (Aug. 17, 1930, K. HARA).

On *Betula Tauschii* KOIDZ. (Shirakamba)

Hokkaido—Prov. Iburi: Tomakomai (Oct. 17, 1904, K MIYABE & J. HANZAWA. Prov. Ishikari: Mt. Sapporo-dake (Sept. 5, 1921, K. TOGASHI); Mt. Maruyama (Aug. 29, 1924, Oid. Y. HOMMA; Oct. 14, 1925, Y. HOMMA, type); Mt. Moiwa (Sept. 7, 1925, Y. HOMMA); Mt. Soranuma (Sept. 18, 1930, Y. TOKUNAGA). Prov. Kitami: Oniwaki, Rishiri-Isl. (Oct. 11, 1923, K. TOGASHI).

Distrib. Japan (Hokkaido and Honshu).

Remarks. The powdery mildew on Betula has hitherto been treated as *Uncinula Salicis*, but in our form it seems to differ from it by the following characters. In the present species, the perithecia and ascospores are smaller in size, and the appendages are fewer in number and sometimes geniculate or flexuous at the upper half. On the other hand, the present fungus resembles rather *U. carpinicola* and *U. geniculata*. The appendages of the former are mostly more delicate and narrowed, while those of the latter are similar to our species in being geniculate, but *U. geniculata* is comparatively smaller in all points and the circinate part of the appendages more narrowed. The present fungus not being referable to any other species of *Uncinula*, the writer has considered it as a new species.

Uncinula carpinicola HARA

(Pl. IX, fig. 13)

Dendropath. p. 16, 1923. (in Japanese). (Shirai & Hara, List, p. 402, 1927).

Syn. *Uncinula geniculata* GER. var. *carpinicola* HARA, Journ. Forest. Assoc. Jap. No. 382, p. 62, 1915; TANAKA, Mycolog. XI, p. 80, 1919; SACC. Syll. Fung. XXIV, p. 223, 1928.

Amphigenous, mycelium subevanescent, thinly effused on the upper surface of the leaf; perithecia 77–112 μ in diameter, globose or depressed-globose; cells 9.6–14.4 × 8.4–13.2 μ in size; appendages 20–23 in number, aseptate or uniseptate, the former hyaline and the latter light brown colored under the septum, straight, thin-walled, 154–231 μ long, enlarged upwards, 4.8–5.6 μ in width, apex simple, circinate; asci 5–10, hyaline, globose or ovate, thin-walled, without stalk, rarely short stalked, 43.2–57.6 × 32.4–45.6 μ; spores 8, ellipsoidal, oblong or elongate-ovate, 17.4–21.6 × 9.6–10.8 μ.

Hab. On leaves of *Carpinus laxiflora* BL. (Akashide). Honshu—Suruga.
Distrib. Japan (Honshu).

Remarks. In 1915, HARA treated the present fungus as a new variety of *Uncinula geniculata*, but in 1923, he elevated it to a new species in his Dendropathology (in Japanese). According to his note, the characteristic points of this fungus are the small size of perithecia and long appendages, 1.5 to 4 times the diameter of the perithecium, additional to which the writer has found the following

characters: the appendages are enlarged from the basal part of the circination and the number of spores is always 8.

Uncinula Fraxini MIYABE

(Pl. IX, fig. 14)

in SALM. Monogr. Erysiph. p. 119, 1900; SACC. Syll. Fung. XVI, p. 400, 1902; TAI & WEI, Sinensia, III, p. 105, 1932. (SALM. Bull. Torr. Bot. Club, XXVII, p. 447, 1900, and Ann. Myc. VI, p. 12, 1908; MATSUM. Ind. Plant. Jap. I, p. 178, 1904; SHIRAI, List, p. 102, 1905; IDETA, Jap. Phytopath. p. 214, 1911; I. MIYAKE, Bot. Mag. Tokyo, XXVIII, p. 39, 1914; SHIRAI & MIYAKE, List, p. 675, 1917; HARA, Dendropath. p. 22, 1923; SHIRAI & HARA, List, p. 402, 1927).

Amphigenous, mycelium evanescent; perithecia depressed-globose or lenticular, 84–102.7 μ in diameter, gregarious or scattered; cells 12–18 μ wide; appendages 17–25 in number, usually aseptate or sometimes 1-septate at the base, hyaline or brown colored toward the base, simple, refractive in the upper half and sometimes flexuous, apex circinate, 154–238 μ in length; asci 5–6 in number, subglobose or ovate, granulate, stalked, 43.2–52.8 × 38.4–43.2 μ; spores 7–8, ellipsoidal or elongate-ellipsoidal, 16.8–19.2 × 9.6 μ.

Hab. On leaves of *Fraxinus japonica* BLUME (Toneriko). Hokkaido—Iburi. Honshu—Rikuchu, Musashi, Echigo, Aki.

On *Fraxinus longicuspis* SIEB. & ZUCC. (Kobano-toneriko). Hokkaido—Iburi, Ishikari.

On *Fraxinus mandschurica* RUPR. (Yachidamo). Hokkaido—Ishikari, Kushiro. Honshu—Rikuchu, Echigo.

On *Fraxinus Sieboldiana* BL. (Aodamo). Hokkaido—Ishikari. Honshu—Rikuchu.

Distrib. Japan (Hokkaido and Honshu) and China.

Remarks. In 1900, the note and specimens of this fungus were sent from Prof. MIYABE to Prof. SALMON, who published it under the present name. In this group, this form has the longest appendages which are somewhat undulately curved but never abruptly bent.

In the form on *Fraxinus japonica* (Mt. Hayachine, Prov. Rikuchu, Sept. 7, 1920, K. TOGASHI), the fungus is very small in all points, the perithecia being 84 μ in diameter, and the appendages only 4 in number. This form may better be treated as var. *minor* HOMMA.

Uncinula Miyabei (SALM.) SACC. & SYD.

(Pl. IX, figs. 15, 16)

SACC. Syll. Fung. XVI, p. 401, 1902. (SHIRAI, List, p. 102, 1905; SALM. Ann. Myc. III, p. 253, 1905, and Ann. Myc. VI, p. 12, 1908; SYD. Ann. Myc. VII, p. 170, 1909, and Ann. Myc. XI. p. 114, 1913; IDETA, Jap. Phytopath. p. 214, 1911, and Jap. Phytopath. (Suppl. 1) p. 214, 1923; SAWADA, Agric. Exp. Stat. Formosa, Bull. IX, p. 69, 1914; SHIRAI & MIYAKE, List, p. 677, 1917; HARA, Dendropath. p. 23, 1923; SHIRAI & HARA, List, p. 402, 1927).

Syn. *Uncinula Salicis* (DC.) WINT. var. *Miyabei* SALM. Monogr. Erysiph. p. 88, 1900. (SALM. Bull. Torr. Bot. Club, XXVII, p. 447, 1900; SHIRAI, List, p. 103, 1905; SHIRAI & MIYAKE, List, p. 679, 1917).

Uncinula Miyabei SALM. Bull. Torr. Bot. Club, XXIX, p. 97, 1902. (MATSUM. Ind. Plant. Jap. I, p. 178, 1904).

Amphigenous, mycelium evanescent or subpersistent, forming thin effused film; conidia solitary, cylindrical, vacuolate, 26.4–31.2 × 10.8–12.4 μ; perithecia gregarious or scattered, depressed-globose, 98.4–127.2 μ in diameter; cells 10.8–14.4 × 9.5–12.0 μ in size; appendages 13–31 in number, 112–168 μ long, simple, usually aseptate or occasionally uniseptate at the base, straight or frequently 1–3 times flexuous or abruptly bent in the upper half, rarely dichotomous, hyaline or pale brown colored toward the base, thin-walled, enlarged upwards, apex uncinate; asci 4–11, globose or broadly ovate, with or without stalk, 43.2–66.0 × 36.0–51.6 μ; spores 5–6 in number, subglobose or ellipsoidal, including the well-developed fibrosin bodies, 18.0–26.4 × 10.8–15.6 μ.

Hab. On leaves of *Alnus cylindrostachys* MAKINO (Miyama-kawara-hannoki). Honshu—Musashi.

On *Alnus pendula* MATSUM. (Hime-yashabushi). Honshu—Inaba.

On *Alnus hirsuta* TURCZ. (Ke-yama-hannoki). Hokkaido—Ishikari. Honshu—Rikuchu, Echigo.

On *Alnus hirsuta* TURCZ. var. *sibirica* SCHNEID. (Yama-hannoki). Hokkaido—Iburi. Honshu—Musashi, Echigo, Kaga.

On *Alnus japonica* SIEB. & ZUCC. (Hannoki). Hokkaido—Shiribeshi, Ishikari. Honshu—Rikuchu, Ugo, Musashi, Echigo, Etchu, Kaga.

On *Alnus japonica* SIEB. & ZUCC. var. *arguta* CALL. (Yezo-hannoki). Hokkaido—Ishikari.

On *Tilia japonica* SIMK. (Shinanoki). Hokkaido—Ishikari.

On *Tilia Maximowicziana* SHIRASAWA (Ohba-bodaiju). Hokkaido—Ishikari.

Distrib. Japan (Hokkaido and Honshu) and Manchuria.

Remarks. The present species was first regarded by SALMON as a variety of *Uncinula Salicis* under the name of var. *Miyabei* SALM. Afterward SACCARDO and SYDOW elevated it to specific rank. In this species compared with *U. Salicis*, the appendages of the perithecium are flexuous and frequently abruptly bent, and rarely dichotomous, also the number of the appendages is generally less. In form the appendages are rather related to *U. Mori* and *U. geniculata*. In *U. Mori*, the appendages are regularly flexuous and their apices more narrowed and smaller. From *U. geniculata*, *U. Miyabei* differs by the less geniculate appendages.

Uncinula Mori I. MIYAKE

(Pl. IX, fig. 17)

Bot. Mag. Tokyo, XXI, p. 1, 1907; SACC. Syll. Fung. XXII, p. 23, 1910. (IDETA, Jap. Phytopath. p. 213, 1911; I. MIYAKE, Bot. Mag. Tokyo, XXVI, p. 53, 1912, and Rep. Sericult. Exp. Stat. I, p. 307, 1916; SHIRAI & MIYAKE, List, p. 677, 1917; SHIRAI & HARA, List, p. 402, 1927).

Epiphyllous, rarely hypophyllous, mycelium subpersistent or evanescent, thinly effused forming roundish patches on the upper surface of the leaves; perithecia scattered or gregarious, 100–112 μ in diameter, globose or depressed-globose; cells 15.6–19.2 × 12.0–14.4 μ in size; appendages 16–22 in number, simple, hyaline, 126–168 μ long, flexuous and abruptly bent at the upper portion, thick-walled toward the base, apex narrowed, circinate or uncinate; asci 2–6 in number, globose or subglobose, granulate, without stalk, 50.4–55.2 × 38.4–45.6 μ; spores 3–5, usually 5, ellipsoidal or elongate-ellipsoidal, granulate, 24.0–27.6 × 13.2–14.4 μ.

Hab. On leaves of *Morus bombycis* KOIDZ. (Yama-guwa). Hokkaido—Ishikari, Kushiro. Honshu—Musashi, Echigo, Kaga, Inaba. Shikoku—Tosa.

Distrib. Japan (Hokkaido, Honshu and Shikoku).

Remarks. This species is parasitic usually on the upper surface of the leaves of Morus, but sometimes on the edges of the under-surface too. The mycelial hyphae are thinly effused in a cobweb manner. This species is nearly related to *U. Miyabei*, but differs from it by the appendages being regularly flexuous and fewer in number, and the circinate part being narrower and smaller.

Uncinula Nishidana HOMMA, *sp. nov.*

(Pl. IX, fig. 18)

Amphigena, plerumque epiphylla; mycelio epiphyllo persistente; peritheciis gregariis, 98–126 μ. diam., globosis v. globoso-depressis, nigris, cellulis obscuris, 16.0–24.0 × 12.0–16.8; appendicibus paucis, 9–13, hyalinis, continuis, 84–120 μ. longis, superne flexuosis, granulatis, apice summo plerumqua uncinatis, raro circinatis; ascis 3–4 in quoque perithecio, late ellipsoideis, brevissime pedicellatis, 51.6–62.4 × 36.0–45.6, 4–5-sporis; sporidiis ellipsoideis v. ovatis, 19.2–25.2 × 12.0–14.4.

Hab. On leaves of *Sterculia platanifolia* L. (Aogiri)

Kyushu—Prov. Higo: Kumamoto (Nov. 3, 1924, S. MIYAMOTO, type); Prov. Osumi: Kanoya (Oct. 1, 1907, Oid. K. YOSHINO).

Distrib. Japan (Kyushu).

Remarks. This species is closely related to *Uncinula Mori* and *U. Miyabei* in respect to the appendages being flexuous and frequently abruptly bent in the upper half. But, in this species the appendages are less in number and shorter, the asci and ascospores are smaller, the appendages are the same in width throughout, and the outer wall cells of the perithecium are comparatively larger. The present species was named after the late Dr. T. NISHIDA, who had made a great contribution to the Mycological Flora of Kyushu.

Uncinula necator (SCHWEIN.) BURR.

in ELL. & EVERH. N. Amer. Pyren. p. 15, 1892; MAGNUS, Erysiph. Tirol. p. 22, 1898; SALM. Monogr. Erysiph. p. 99, 1900, and Bull. Torr. Bot. Club, XXIX, p. 99, 1902; LIND, Danish Fung. p. 164, 1913; KLIKA, Erysiph. Czechosl. p. 50, 1924; ŠKORIĆ, Erysiph. Croat. p. 41, 1926. (RANOJ. Hedw. XLI, p. 102, 1902; MATSUM. Ind. Plant. Jap. I, p. 178, 1904; SHIRAI, List, p. 103 (p.p.), 1905; SALM. Ann. Myc. III, p. 253, 1905; LAWR. Journ. Myc. XI, p. 108, 1905; YOSHINO, Bot. Mag. Tokyo, XIX, p. 206, 1905; IDETA, Jap. Phytopath. p. 206, 1911; SAWADA, Agric. Exp. Stat. Formosa, Bull. IX, p. 67, 1914, and XIX p. 177, 1919; DOIDGE, Roy. Soc. South Afr. V, p. 240, 1915; SHIRAI & MIYAKE, List, p. 677, 1917; SHIRAI & HARA, List, p. 403, 1927).

Syn. *Erysiphe necator* SCHWEIN. Syn. Fung. Am. Bor. p. 270, 1834; SACC Syll. Fung. I. p. 22, 1882.

Erysiphe Tuckeri BERK. Journ. Hort. Soc. London, IX, p. 66, 1855; KICKX, Crypt. Fl. Fland. I, p. 382, 1867; DE BARY, Beitr. Morph. Phys. Pilz, I, xiii, p. 50, 1870; SACC. Syll. Fung. I, p. 20, 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 34, 1884. (SHIRAI, List, p. 32, 1905; SHIRAI & MIYAKE, List, p. 227, 1917).

Sphcerotheca Castagnei v. *Vitis* FUCK. Symb. Myc. p. 79, 1869–70.

Uncinula ampelopsidis PECK, Trans. Albany Inst. VII, p. 216, 1872; SACC. Syll. Fung. I, p. 7, 1882; BURR. & EARLE, Bull. Ill. Stat. Lab. Nat. Hist. II, p. 406, 1887. (TRACY & GALLOW. Journ. Myc. IV, p. 35, 1888; PAMM. Journ. Myc. IV, p. 37, 1888).

Uncinula americana E. C. HOWE, Journ. Bot. II, p. 170, 1872; SACC. Syll. Fung. I, p. 8, 1882; PRILL. Malad. Pl. Agr. II, p. 17, 1897. (SHIRAI, List, p. 102, 1905; SHIRAI & MIYAKE, List, p. 673, 1917).

Erysibe Tuckeri (BERK.) SCHRÖT. in COHN's Krypt. Fl. Schles. III, p. 241, 1893.

Uncinula spiralis BERK. & CURT. Grev. IV, p. 159, 1876; JACZEW. Bull. l'Herb. Boiss. IV, p. 739, 1896. (COOKE & PECK, Journ. Bot. I, p. 170, 1872; SHIRAI, List, p. 103, 1905; SHIRAI & MIYAKE, List, p. 679, 1917).

Oidium Tuckeri BERK. Garden. Chron. p. 779, 1847; SACC. Syll. Fung. IV, p. 41, 1886; LIND. in RABENH. Krypt. Fl. Deutschl. VIII, p. 84, 1907.

Amphigenous, usually epiphyllous, mycelium persistent on the upper leaves sometimes on the inflorescences or young fruits; "perithecia usually epiphyllous, sometimes hypophyllous, occasionally occurring on the inflorescence, globose-depressed, more or less scattered, 70–128 μ in diameter, averaging 98 μ, cells distinct, rather irregular in shape, 10–20 μ wide, appendages very variable in number and length, 7–32, rarely irregularly crowded and as many as 40, 1–4 times the diameter of the perithecium, smooth, simple, septate, thin-walled, light or dark amber-brown in the lower half, flexuous and flaccid when long, subrigid and straight when shorter, apex more or less helicoid when mature, often strongly so; asci 4–6, rarely 6–9, broadly ovate or ovate-oblong to subglobose, with or without a short stalk, 50–60 × 30–40 μ; spores 4–7, 18–25 × 10–12 μ." (acc. to SALMON, Monogr. Erysiph. p. 99).

Hab. On leaves of *Vitis vinifera* L. (Seiyo-budo). Honshu—Kai, Settsu. Kyushu—Higo.

On *Ampelopsis heterophylla* SIEB. & ZUCC. (Nobudo). Hokkaido—Ishikari.

Distrib. Japan (Hokkaido, Honshu, Kyushu and Formosa), Manchuria, North America, Europe and South Africa.

Remarks. The writer unfortunately could not find the perithecial stage of *U. necator* in Japan, although the conidial stage has been collected in different parts of this country.

Oidium belonging to Uncinula

On *Rosa indica* L. var. *formosana* HAY. (Koshin-bara). *Oidium Rosae-indicae* SAW. (According to SAWADA, Depart. Agr. Govern. Research Inst. Formosa, Japan, No. 61, p. 82, 1933).

On *Alangium platanifolium* BAILL. var. *macrophyllum* WAG. (Urinoki). Honshu—Musashi.

On *Cephalanthus occidentalis* L. (Tamagasanoki). *Oidium Cephalanthi* SAW. (According to SAWADA, Depart. Agr. Govern. Research Inst. Formosa, Japan, No. 61, p. 81, 1933).

Typhulochaeta S. ITO & HARA

Mycelium is superficial, haustoria are epidermal and subglobose in shape; perithecia are globose or depressed-globose, including several asci in a perithecium; appendages are simple and clavate in shape. The genus is represented by only one species.

Typhulochaeta *japonica* S. ITO & HARA

(Pl. IX, fig. 19)

Bot. Mag. Tokyo, XXIX, p. 20, 1915, and Trans. Sapporo Nat. Hist. Soc. V, p. 198, 1915; HARA, Journ. Forest. Assoc. Japan, No. 392, p. 61, 1915; SACC. Syll. Fung. XXIV, p. 226, 1926. (HARA, Dendropath. p. 24, 1923; IDETA, Jap. Phytopath. (Suppl. I), p. 216, 1923; SHIRAI & HARA, List, p. 401, 1927).

Amphigenous, usually hypophyllous, mycelium persistent or subevanescent, forming thin effused film; perithecia scattered or subgregarious, globose or depressed-globose, 154–182 μ in diameter; cells 9.6–12.0 μ in width; appendages springing from the upper part of the perithecium from a broad coronate ring composed of two or three rows, 96–142 in number, about 50–63 μ in length, 12–15 μ in width, hyaline, clavate, simple, rounded at apex, thick-walled; asci 5–13, ovate or ellipsoidal, stalked, 70.0–97.0 $\times$ 33.6–55.0 μ; spores 8, rarely 6, oblong or ellipsoidal, 19.2–36.0 $\times$ 12.0–18.0 μ.

Hab. On leaves of *Quercus aliena* BLUME (Nara-gashiwa). Kyushu—Higo.
On *Quercus crispula* BLUME (Mizu-nara). Honshu—Rikuchu, Echigo.
On *Quercus serrata* THUNB. (Ko-nara). Honshu—Suruga, Mino, Totomi, Yamashiro. Kyushu—Higo.
On *Fraxinus japonica* BLUME (Toneriko). Honshu—Totomi.
Distrib. Japan (Honshu and Kyushu).

Remarks. The present genus was first described in 1915 by Prof. S. ITO. By the clavate appendages of the perithecium it can be distinguished from all other genera of Erysiphaceae, moreover these appendages spring from the upper part of the perithecium in the form of a broad coronate band composed of 2–3 rows. According to Prof. ITO, the appendages "are simple and clavate in shape, with a close resemblance to the fructification of a species belonging to the genus Typhula of Basidiomycetes in their outlines, and also to the immature stage of the penicillate cells of Phyllactinia". The penicillate cells of Phyllactinia are also produced on the upper part of the perithecium forming a coronate ring composed of one to three rows, but always accompanied by the appendages. In the present genus, the appendages are constant in shape, being clavate and simple, never producing the penicillate bodies.

Quercus crispula, *Q. aliena* and *Fraxinus japonica* were added as new hosts to this species.

In order to collect the conidia of this species, in the early part of August in 1930, the writer made a collecting trip to Shizuoka Prefecture, where this fungus was collected in the previous year by Mr. HARA. But no conidial formation could be found except a white thin effused mycelial film on the leaves of *Quercus serrata*. In September of the same year Mr. HARA kindly sent a specimen which was found to be also in the mycelial stage. Thus, the conidial stage of this species is still lacking.

Sawadaea MIYABE

Mycelium is superficial, forming haustoria in the epidermal cells of the host plants; matured conidia are produced in a chain, including well-developed fibrosin bodies; perithecia are depressed-globose or concave, including several asci; appendages spring from the upper part of the perithecium and are simple or dichotomously branched, sometimes trichotomously, and are colorless and thick-walled.

In 1914, this genus was separated from Uncinula by MIYABE under a new generic name of Sawadaea. It was first published by SAWADA, *in* Agric. Exp. Stat. Formosa, Spec. Bull. IX, p. 49. (in Japanese). The original description is as follows:

Amphigenous, mycelium superficial, more or less persistent, white powdery at first and finally turning to a grayish color, sending haustoria into epidermal cells, globose in shape; conidia have both stages of micro- and macro- forms, conidiophores straight, branching from the creeping mycelium, at the branching point swelling a little, conidia produced in a chain, including fibrosin bodies, elongate-octahedron in shape; perithecia depressed-globose, numerous appeandages arise from the upper part of the perithecium, hyaline, straight, dichotomously or trichotomously branched or simple, apex helicoid, asci numerous, spores 8, elongate-ellipsoidal.

In the conidial stages the present genus comes closer to Podosphaera than to Uncinula. In the perithecial stages it nearly resembles Uncinula, from which it differs by the appendages arising from the upper part of the perithecium and being dichotomously or trichotomously branched.

In the present genus, the most important point of distinction from genus Uncinula is in the character of the appendages of the perithecium which are regularly dichotomously branched while the appendages of the species of Uncinula are rarely irregularly branched.

This genus includes 3 species in this country.

Key to the species of the genus Sawadaea

I. Appendages always dichotomously or trichotomously branched and simple appendages very few .... *S. bicornis* (371)

II. Appendages dichotomously or trichotomously branched to $\frac{2}{3}$ of all numbers in a perithecium and others simple.

1. Mycelium persistent, densely thickened .... *S. Tulasnei* (374)
2. Mycelium evanescent, thinly effused .... *S. Negundinis* (375)

Sawadaea bicornis (WALLR.) MIYABE nom. nov.

(Pl. IX, fig. 20)

Syn. *Erysiphe aceris* DC. Syn. Pl. Fl. Gall. p. 57, 1806, and Fl. Fr. VI. p. 104, 1815; MÉRAT, Nouv. Fl. Paris, p. 75, 1837, and Syn. Nouv. Fl. Paris p. 84, 1837; TULASNE, Selecta Fung. Carpolog. I, p. 197, 1861; DE BARY, Beitr. Morph. Phys. Pilz. I, xiii, p. 52, 1870.

Erysiphe varium FR. Obs. Myc. I, p. 206 (p.p.), 1815.

Alphitomorpha bicornis WALLR. Berl. Ges. Nat. Freund. Verh. I, p. 38, 1819.

Erysibe bicornis LK. in WILLD. Sp. Pl. VI, p. 112, 1824; RABENH. Deutschl. Krypt. Fl. I, p. 235, 1844.

Erysiphe bicornis FR. Syst. Myc. III, p. 244 (p.p.), 1829; CORDA, Icon. Fung. II, p. 28, 1838.

Uncinula Aceris SACC. Syll. Fung. I, p. 8, 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 41, 1884; ELL. & EVERH. N. Amer. Pyren. p. 17, 1892; SCHRÖT. in COHN's Crypt. Fl. Schles. III, p. 246, 1893; JACZEW. Bull. l'Herb. Boiss. IV, p. 738, 1896; OUDEM. Rév. Champ. Pays-Bas, II, p. 88, 1897; MAGNUS, Erysiph. Tirol. p. 21, 1898; SALM. Monogr. Erysiph. p. 90 (p.p.), 1900, and Bull. Torr. Bot. Club, XXIX, p. 97, 1902; NEGER, Krypt. Fl. d. Mark Brand. VII, p. 131, 1905; KLIKA, Erysiph. Czechosl. p. 49, 1924; JØRST. Erysiph. Norway, p. 101, 1925; ŠKORIĆ, Erysiph. Croat. p. 41, 1926. (SALM. Ann. Myc. VI, p. 12, 1908; RANOJ. Hedw. XLI, p. 102, 1902; SHIRAI & MIYAKE, List, p. 673 (p.p.), 1917).

Uncinula bicornis LÉV. Ann. Sci. Nat. III, 15, p. 153 (p.p.), 1851; KICKX, Fl. Crypt. Fland. I, p. 377, 1867; COOKE, Handb. Brit. Fung. I, p. 647, 1871; QUÉL. Champ. Jur. Vosg. p. 533, 1875; LIND, Danish Fung. p. 164, 1913. (FUCK. Symb. Myc. p. 80, 1869–70).

Oidium Aceris RABENH. Flora, XXXVII, p. 207, 1854; SACC. Syll. Fung. IV, p. 44, 1886; LIND. in RABENH. Krypt. Fl. Deutschl. VIII, p. 81, 1907.

Amphigenous, mycelium evanescent; perithecia scattered, 175–196 μ in diameter, depressed-globose; cells 10.8–12.0 $\times$ 7.2–8.4 μ; appendages numerous, about 126–140 μ in length, hyaline, aseptate, thick walled throughout, bifurcate at the upper half or rarely trifid, very few simple (2 or 3 in a perithecium), apex uncinate or helicoid; asci about 14 in number, ellipsoidal or elongate-ellipsoidal, with or without stalk, 66.4–81.6 $\times$ 38.4–44.4 μ; spores 8, elongate-ellipsoidal or elongate-ovate, 16.8–26.4 $\times$ 12.0–14.4 μ.

Hab. On leaves of *Acer cissifolium* C. KOCH. (Mitsuba-kaede). Honshu—ikuchu.

Distrib. Japan (Honshu), Transcaucasia and Europe.

Remarks. This species can be distinguished from others at once by the appendages which are almost all dichotomous or trichotomous, and also by the mycelium which becomes evanescent when the perithecia are produced on the leaves. According to SALMON's description in *Uncinula Aceris* "mycelium evanescent or persistent as a thin effused film; appendages usually a very few simple, the rest bifid" and in *Uncinula Aceris* var. *Tulasnei* "mycelium usually epiphyllous, very rarely amphigenous, persistent, densely compacted, forming either roundish circumscribed spots or irregular blotches following the veins of the leaf; appendages simple or bifid (usually mostly simple, inter-mixed with a few bifid ones)".

In the fungus which has been known as *Sawadaea Aceris* MIYABE the mycelium is very densely compacted and persistent, and the simple appendages exist to more than $\frac{1}{3}$ of the total number in a perithecium; therefore, these specimens must be transferred to *Sawadaea Tulasnei* HOMMA. In 1908, the form on *Acer cissifolium* was described as *Uncinula Aceris* by SALMON. (Ann. Myc. VI, p. 12). This specimen evidently belongs to *Sawadaea Aceris*, as the mycelium is evanescent when the perithecia are formed, the simple appendages are only 2 or 3 in a perithecium and the size of the asci is larger than in *Sawadaea Tulasnei*.

The writer paid special attention to the presence of the micro- and macro-conidia in Sawadaea and Uncinula parasitic on Acer. On *U. circinata* and *S. Aceris*, the micro-conidia have not been observed up to the present time. *Oidium Aceris* RABENH. is a macro-form from its shape and size, and it belongs to the conidial stage of *U. Aceris* judging by its host plant and symptom. On the other hand, as the result of the examination of many exotic herbarium specimens of *U. circinata* from America and *U. Aceris* from Europe, it was found that they all have macro-conidia in concatenate chain, while the micro-conidia could not be found in spite of careful observation. In *S. Tulasnei* both forms of conidia have hitherto been reported by many authors, and have also been observed in many Japanese specimens.

The form on *Acer cissifolium* is the typical *Sawadaea Aceris*, but this specific name was proved to be a synonym of *Sawadaea Tulasnei*. Therefore, the next older name was used for this species.

Sawadaea Tulasnei (FUCK.) HOMMA, comb. nov.
(Pl. IX, fig. 21)

Syn. *Erysiphe bicornis* FR. Syst. Myc. III, p. 244 (p.p.), 1829.

Uncinula bicornis LÉV. Ann. Sci. Nat. III, 15, p. 135 (p.p.), 1851.

Uncinula Tulasnei FUCK. Fung. Rhenani exsiccati, No. 1746, 1866, and Symb. Myc. p. 81, 1869–70; SACC. Syl. Fung. I, p. 9, 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 41, 1884; JØRST. Erysiph. Norway, p. 102, 1925.

Uncinula Aceris (not SACC.) SALM. Monogr. Erysiph. p. 90 (p.p.), 1900. (SALM. Bull. Torr. Bot. Club, XXVII, p. 446, 1900, and Ann. Myc. III, p. 252, 1905; P. HENN. in ENGL. Bot. Jahrb. XXXII, p. 42, 1903; NAMBU, Bot. Mag. Tokyo, XVIII, p. 2, 1904; MATSUM. Ind. Plant. Jap. I, p. 178, 1904; SHIRAI, List, p. 102, 1905; IDETA, Jap. Phytopath. p. 214, 1911; SYDOW, Ann. Myc. XI, p. 114, 1913; SHIRAI & MIYAKE, List, p. 673 (p.p.), 1917).

Sawadaea Aceris MIYABE, in SAWADA, Agric. Exp. Stat. Formosa, Bull. IX, p. 50, 1914. (HARA, Dendropath. p. 9, 1923; IDETA, Jap. Phytopath. (Suppl. I), p. 209, 1923; SHIRAI & HARA, List, p. 350, 1927).

Uncinula Aceris SACC. var. *Tulasnei* SALM. Monogr. Erysiph. p. 93, 1900; KLIKA, Erysiph. Czechosl. p. 50, 1924. (I. MIYAKE, Bot. Mag. Tokyo, XXVIII, p. 39, 1914).

Amphigenous, mostly epiphyllous, mycelium persistent, in densely compacted patches having a white or grayish color with a silky lustre, especially growing in a net-work manner on the veinlets of the leaf; matured conidia produced in a chain, including well-developed fibrosin bodies, macro-conidia ellipsoidal, 21.6–30.0 × 13.2–18.0 μ, micro-conidia globose or subglobose, 7.2–9.6 × 7.2–8.4 μ; perithecia depressed-globose or lenticular, 154–189 μ in diameter; cells 12.6–16.8 × 9.6–12.0 μ in size; appendages numerous (about 70), 69.6–91.2 μ in length, aseptate, colorless, simple or dichotomous, rarely trichotomous, apex uncinate or helicoid, thick-walled; asci 8–15 in number, subtriangular or ovate, with a short stalk, 64.8–76.8 × 34.8–39.6 μ; spores 7–8 in number, usually 8, oblong or ellipsoidal, 12.0–19.2 × 10.8–13.2 μ.

Hab. On leaves of *Acer crataegifolium* SIEB. & ZUCC. (Urikaede). Honshu—Echizen.

On *Acer Miyabei* MAXIM. (Kurobi-itaya). Hokkaido—Ishikari.

On *Acer Mayrii* GRAF. v. SCHW. (Beni-itaya). Hokkaido—Ishikari, Kushiro.

On *Acer palmatum* THUNB. (Yama-momiji). Hokkaido—Ishikari. Honshu—Rikuchu, Musashi, Echigo. Kyushu—Satsuma.

On *Acer pictum* THUNB. (Itaya-kaede). Hokkaido—Shiribeshi, Iburi, Ishikari, Hidaka, Kushiro. Honshu—Rikuchu, Rikuzen, Shimozuke, Musashi, Yamashiro.

On *Acer ukurunduense* TRAUTV. & MEY. (Ogarabana). Hokkaido—Ishikari.

Distrib. Japan (Hokkaido, Honshu, Kyushu and Formosa), Manchuria and Europe.

Remarks. The fungus which occurs on *Acer Miyabei, A. palmatum* and *A. pictum* has hitherto been identified to *Sawadaea Aceris*, but the author thinks it had better be changed to *Sawadaea Tulasnei* for the following reason.

The mycelium of the fungus in question has a white silvery lustre, presenting dense meshes along the veinlets of the leaf, the simple appendages are from $\frac{1}{2}$ to $\frac{1}{3}$ of the total number in a perithecium and the size of the asci is smaller than in the case of *Sawadaea bicornis*.

Uncinula Tulasnei was treated as a variety of *U. Aceris* by SALMON, but from the above characters, the present author has come to the conclusion that it had better be elevated to specific rank rather than to be considered as a variety.

The present species has conidia of both types of micro- and macro-forms; the macro-conidia occur in early July and the micro-conidia arise on the same leaves in late August, in the vicinity of Sapporo. After August, the macro-conidia disappear and the micro-conidia are abundantly produced on the leaves. The macro-conidial stage presents a powdery white appearance, and the micro-conidial stage a shining white and compactly smooth appearance, so that one can easily distinguish the two stages with the naked eye.

The perithecia of this fungus have a peculiar character of turning over when mature.

The present species is a most common powdery mildew on Acer in this country, and is very widely distributed.

Sawadaea Negundinis HOMMA, sp. nov.

(Pl. IX, fig. 22)

Amphigena, plerumque hypophylla; mycelio tenui evanido v. effuso-subpersistente; peritheciis magnis, sparsis v. subgregariis.

globosis v. globoso-depressis, 140–182 μ. diam., cellulis 4.8–9.6 μ diam.; *appendicibus 68–90, hyalinis, crassius tunicatis, 72–90 μ. longis* continuis, dichotome v. raro trichotome ramosis v. simplicibus, apic uncinatis v. helicoideis; *ascis 6–16 in quoque perithecio, ovatis v* triangularibus, 51.6–67.2 × 33.6–43.2, cum v. sine brevi pedicello, 7-8-sporis; sporidiis subglobosis, ellipsoideis v. reniformis, 16.8–19.2 × 8.4–13.2; conidiis 3–4 concatenatis, intus fibrosin-corpuscula e granula nitida, pallide viridi-gilva continentibus, macro-conidiis ellipsoideis v. oblongo-ellipsoideis, 25.2–32.4 × 16.8–18, micro-conidii globosis v. subglobosis, 7.2–8.6 × 5.6–7.2.

Hab. On leaves of *Acer Negundo* L. (Toneriobano-kaede)

Hokkaido—Prov. Ishikari: Sapporo (July 21, 1922, Y. HOMMA; Sept. 8 1922, Y. HOMMA; Sept. 18, 1922, S. ITO; Oct. 5, 1922, Y. HOMMA; Oct. 21, 1922 Y. HOMMA, type; Oct. 4, 1923, Y. HOMMA; Sept. 9, 1924, Y. HOMMA); Maruyama (Oct. 24, 1929, M. TERUI; Oct. 25, 1930, Y. HOMMA); Shinotsumura (Sept. 11 1933, K. YOSHINO).

Distrib. Japan (Hokkaido).

Remarks. This species has been collected only in the vicinity of Sapporo on the introduced American ash-leaved maple. The author at first identified it as *Sawadaea Aceris*. However, she has found on careful examination that although the mycelium is thin as in that species, the size of the asci and ascospores are smaller and the character of the appendages approaches nearer to that of *Sawadaea Tulasnei;* micro-conidia are present also.

As to the relation to *Sawadaea Tulasnei*, the mycelium of that species is mostly epiphyllous, and densely shining white, while in the present species the mycelium is usually hypophyllous, thinly effused and the simple appendages reach to about a half of the whole number on a perithecium.

As the result of careful observations, the present fungus could be identified neither to *S. Aceris* nor *S. Tulasnei*, therefore it must be considered as a new species.

Microsphaera LÉV.

Mycelium is superficial, sending haustoria into the epidermal cells of the host plants; haustoria are globose or subglobose in shape;

matured conidia are solitary, almost ellipsoidal in shape, includin vacuoles and granules, without well developed fibrosin bodies; per thecia are globose or depressed-globose, always small-sized; appenc ages are dichotomously branched at the apex; asci and ascospores ar several.

This genus can be divided into two sections of *Alni* and *Diffusı* In the former, the tips of the ultimate branches of appendages ar recurved, and in the latter straight and not recurved.

In Japan, 17 species of this genus have been found. Amon them 4 species are new to science.

Key to the species of the genus Microsphaera

I. Alni section.

Tips of the ultimate branches of appendages recurved.

A. Appendages short and regularly branched.

a. Primary dichotomous branches of appendages straight.

1. Appendages very regularly 5-6 times dichotomously branched and branches similar in length. Conidia ellipsoidal..**M. Alni** (37

2. Appendages frequently trichotomously branched .... **M. *calocladophora*** (38

3. Inner secondary branches of the appendages generally pointed in the same direction as the primary. Conidia ellipsoidal or barrel-shaped.................. **M. *alphitoides*** (38

b. Primary dichotomous branches of appendages more or less recurved.

1. Primary branches divided frequently at about the middle or near the base of the appendages.............. **M. *Ligustri*** (38

2. Primary branches divided always at the apical portion ....**M. *divaricata*** (38

B. Appendages long and flaccid, more or less irregularly branched.

a. Appendages more or less regularly branched. Perithecia 112–140 μ in diameter and appendages 196–238 μ in length .... **M. *Coryli*** (38

b. Appendages irregularly branched.

1. Perithecia 91–126 μ in diameter and appendages 84–175 μ in length.................................... **M. *Yamadai*** (39

2. Perithecia 91–112 μ in diameter and appendages very long and flexuous, 336–434 μ in length........... **M. *Euphorbiae*** (39

II. Diffusa section.
Tips of the ultimate branches of the appendages not recurved.
A. Primary branches long.
a. Appendages long and twice to sevenfold the diameter of the perithecia.
1. Appendages 128—308 μ in length, light brown colored toward the base..*M. Abeliae* (392)
2. Appendages about 350—500 μ in length, colored throughout nearly to the apex............................*M. Russellii* (401)
b. Appendages short and about the same as the diameter of the perithecia or slightly longer.
1. Tips of ultimate branches rarely recurved, appendages 126—140 μ in length...............................*M. Lonicerae* (392)
2. Tips of ultimate branches straight, appendages 126—161 μ in length.............................*M. pseudo-Lonicerae* (393)
B. Secondary branches long.
a. Tips of ultimate branches more or less narrowed.
1. Branches of the higher order thick.......... *M. Berberidis* (394)
2. Branches of the higher order slender...... *M. Grossulariae* (396)
b. *Tips of ultimate branches cylindrical.*
1. Appendages 5-6 times dichotomously branched...*M. diffusa* (398)
2. Appendages 2-3 times dichotomously branched..*M. Bäumleri* (399)
C. Primary branches divided in the lower half of the appendages and irregularly 2-3 times dichotomously branched....*M. Viciae-unijugae* (400)

Microsphaera Alni (WALLR.) SALM.

(Pl. X, figs. 1-7)

Monogr. Erysiph. p. 129 (p.p.), 1900, and Bull. Torr. Bot. Club, XXIX, p. 105 (p.p.), 1902; TAI & WEI, Sinensia, III, p. 116 (p.p.), 1932. (SALM. Bull. Torr. Bot. Club, XXVII, p. 444 (p.p.), 1900, Ann. Myc. III, p. 250 (p.p.), 1905, and VI, p. 8 (p.p.), 1908; NAMBU, Bot. Mag. Tokyo, XVIII, p. 3, 1904; MATSUM. Ind. Plant. Jap. I, p. 154 (p.p.), 1904; SHIRAI, List, p. 55 (p.p.), 1905; YOSHINO, Bot. Mag. Tokyo, XIX, p. 205, 1905; IDETA, Jap. Phytopath. p. 205 (p.p.), 1911, and Jap. Phytopath. (Suppl. I), p. 211 (p.p.), 1923; SYD. Ann. Myc. XI, p. 114 (p.p.), 1913; SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 61 (p.p.), 1914; I. MIYAKE, Bot. Mag. Tokyo, XXVIII, p. 39 (p.p.), 1914; SHIRAI & MIYAKE, List, p. 365 (p.p.), 1917; HARA, Dendropath. p. 11 (p.p.), 1923; SHIRAI & HARA, List, p. 215 (p.p.), 1927).

Syn. *Alphitomorpha penicillata* var. *Alni* WALLR. Berl. Ges. Nat. Freund. I, p. 40, 1819.

Alphitomorpha Alni WALLR. Ann. Wett. Ges. IV, p. 237, 1819.

Erysibe penicillata a *Alni* LINK, in Willd. Sp. Pl. VI, p. 113 (p.p.), 1824; MÉRAT, Nouv. Fl. Paris, p. 75 (p.p.), 1837, and Syn. Nouv. Fl. Paris, p. 84 (p.p.), 1837; RABENH. Deutschl. Krypt. Fl. I, p. 236 (p.p.), 1844.

Erysiphe penicillata FR. Syst. Myc. III, p. 243 (p.p.), 1829.

Erysiphe Viburni SCHWEIN. Syn. Fung. Am. Bor. p. 269, 1834; SACC. Syll. Fung. I, p. 21, 1882.

Erysiphe Syringae SCHWEIN. Syn. Fung. Am. Bor. p. 270, 1834; SACC. Syll. Fung. I, p. 21, 1882.

Microsphaera Hedwigii LÉV. Ann. Sci. Nat. III, 15, p. 155, 1851; FUCK. Symb. Myc. p. 81, 1869–70; COOKE, Handb. Brit. Fung. II, p. 648, 1871; COOKE & PECK, Journ. Bot. I, p. 12 (p.p.), 1872; SACC. Syll. Fung. I, p. 11, 1882; OUDEM. Rév. Champ. Pays-Bas, II, p. 90, 1897.

Microsphaera penicillata LÉV. Ann. Sci. Nat. III, 15, p. 155, 1851; KICKX, Fl. Crypt. Fland. I, p. 378, 1867; FUCK. Symb. Myc. p. 81, 1869–70; COOKE, Handb. Brit. Fung. II, p. 649, 1871; SACC. Syll. Fung. I, p. 13 (p.p.), 1882; OUDEM. Rév. Champ. Pays-Bas, II, p. 92, 1897.

Microsphaera Friesii LÉV. Ann. Sci. Nat. III, 15, p. 156, 1851; COOKE & PECK, Journ. Bot. I, p. 12, 1872; SACC. Syll. Fung. I, p. 13, 1882. (TRACY & GALLOW. Journ. Myc. IV, p. 35, 1888).

Erysiphe Alni (not DC.) TULASNE, Selecta Fung. Carpolog. I, p. 203, 1861.

Microsphaera pulchra COOKE & PECK, Journ. Bot. I, p. 12, 1872; SACC. Syll. Fung. I, p. 12, 1882.

Microsphaera penicillata LÉV. var. *Alni* COOKE & PECK, Journ. Bot. I, p. 171, 1872.

Microsphaera sparsa HOWE, in COOKE & PECK, Journ. Bot. I, p. 171, 1872.

Microsphaera Platani HOWE, Bull. Torr. Bot. Club, V, p. 4, 1874; SACC. Syll. Fung. IX, p. 369, 1891.

Microsphaera Viburni HOWE, Bull. Torr. Bot. Club, V, p. 43, 1874; SACC. Syll. Fung. IX, p. 369, 1891.

Podosphaera Hedwigii QUÉL. Champ. Jur. Vosg. p. 534, 1875.

Podosphaera penicillata QUÉL. Champ. Jur. Vosg. p. 534, 1875.

Microsphaera Alni WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 38, 1884; BURR. & EARLE, Bull. Ill. Stat. Lab. Nat. Hist. II, p. 421,

1887; ELL. & EVERH. N. Amer. Pyren. p. 27, 1892; SCHRÖT. in COHN's Krypt. Fl. Schles. III, p. 244, 1893; JACZEW. Bull. l'Herb. Boiss. IV, p. 748, 1896; MAGNUS, Erysiph. Tirol. p. 20, 1898; Neger, Krypt. d. Mark Brand. VII, p. 125, 1905; KLIKA, Erysiph. Czechosl. p. 52, 1924; *JØRST. Erysiph. Norway, p. 95, 1925; ŠKORIĆ, Erysiph.* Croat. p. 53, 1926. (PAMM. Journ. Myc. IV, p. 38, 1888; TRACY and GALLOW. Journ. Myc. IV, p. 35, 1888; GRIFF. Bull. Torr. Bot. Club, XXVI, p. 144, 1899; P. HENN. in ENGL. Bot. Jahrb. XXXII, p. 42, 1903; LAWR. Journ. Myc. XI, p. 106, 1905).

Microsphaera Nemopanthis PECK, Reg. Rep. XXXVIII, p. 102, 1886; SACC. Syll. Fung. addit. ad Vols. I–IV, p. 2, 1886, and SACC. Syll. Fung. IX, p. 368, 1891.

Microsphaera japonica P. HENN. in ENGL. Bot. Jahrb. XXVIII, p. 271, 1901. (SHIRAI, *List*, p. 55, 1905; SHIRAI & MIYAKE, *List*, p. 367, 1917).

Microsphaera Alni (FRIES) WINT. in Lind, Danish Fung. p. 163, 1913.

Amphigenous, mostly hypophyllous, mycelium persistent or evanescent, at first forming irregular white patches or growing along the veins on the upper surface of the leaves; matured conidia solitary, ellipsoidal, vacuolate, granulate, 28.8–45.6 × 15.6–36.0 μ in size; perithecia gregarious or scattered, globose or depressed-globose, 86.4–130 μ in diameter; cells 14.4–19.2 × 9.6–14.4 μ in size; appendages 8–26 in number, aseptate or 1-septate, light brown colored toward the base or brown colored under the first septum, 81.6–154 μ in length, 7.2–9.6 μ in width, 4–6 times (usually 5) dichotomously branched, apex of the ultimate branches regularly and distinctly recurved; asci 3–8, oblong or subglobose, with or without a short stalk, 36.4–81.6 × 30.0–60.0 μ; spores 4–8, oblong or ellipsoidal, 14.4–26.4 × 8.4–14.4 μ in size.

Hab. On leaves of *Alnus hirsuta* TURCZ. (Ke-yama-hannoki). Hokkaido—Ishikari. Honshu—Rikuchu, Echigo.

On *Ostrya japonica* SARG. (Asada). Hokkaido—Ishikari.

On *Castanea crenata* SIEB. & ZUCC. (Kuri). Hokkaido—Oshima, Shiribeshi, Iburi, Ishikari, Kitami. Honshu—Rikuchu, Rikuzen, Musashi, Shimozuke, Echigo, Sado, Etchu, Tamba. Shikoku—Iyo. Kyushu—Buzen, Bungo. Korea—Suigen.

On *Syringa japonica* DECNE. (Hashidoi). Hokkaido—Iburi, Ishikari, Kushiro. Honshu—Echigo.

On *Berchemia racemosa* SIEB. & ZUCC. (Kuma-yanagi). Honshu—Rikuchu.

On *Akebia lobata* DECNE. (Mitsuba-akebi). Honshu—Mutsu, Rikuchu, Uzen.

On *Akebia quinata* DECNE. (Akebi). Honshu—Rikuchu, Musashi, Kaga.

On *Cocculus trilobus* DC. (Aotsuzurafuji). Honshu—Bizen.

On *Schizandra chinensis* BAILL. (Chosen-gomishi). Hokkaido—Oshima, Ishikari.

On *Schizandra nigra* MAXIM. (Matsubusa). Honshu—Rikuchu.

On *Lindera praecox* BLUME (Aburachan). Honshu—Rikuchu.

On *Picrasma quassioides* BENN. (Nigaki). Hokkaido—Shiribeshi, Ishikari. Honshu—Rikuchu, Musashi.

On *Staphylea Bumalda* SIEB. & ZUCC. (Mitsuba-utsugi). Honshu—Rikuchu.

On *Rhamnus dahurica* PALL. var. *nipponica* MAKINO (Ohkuroumemotogi). Honshu—Mutsu, Rikuchu.

On *Cornus controversa* HEMSL. (Mizuki). Hokkaido—Ishikari, Kitami. Honshu—Rikuchu, Musashi.

On *Cornus Kousa* BUERG. (Yama-boshi). Hokkaido—Ishikari. Honshu—Rikuchu.

On *Helwingia japonica* DIETER (Hana-ikada). Honshu—Rikuchu, Musashi, Kaga.

On *Rhododendron macrocepalum* MAXIM. (Mochi-tsutsuji). Honshu—Yamashiro.

On *Styrax japonicum* SIEB. & SUCC. (Egonoki). Honshu—Musashi.

On *Lonicera Chamissoi* BUNGE (Chishima-hyotamboku). Hokkaido—Ishikari.

On *Lonicera ciliata* MUHL. Hokkaido—Ishikari.

On *Lonicera Maackii* HERD. (Hana-hyotamboku). Honshu—Rikuchu.

On *Lonicera Morrowii* A. GRAY (Kingin-boku). Hokkaido—Kurile Isls. Shikotan Isl., Ishikari. Honshu—Ugo.

On *Lonicera orientalis* LAM. Hokkaido—Ishikari.

On *Lonicera tatarica* L. Hokkaido—Ishikari.

Distrib. All over the world.

Remarks. This species is a very common powdery mildew parasitic on numerous trees and its range of distribution is almost cosmopolitan. The characters of the present species as limited here in the present paper are that each dichotomous branch of the appendages is straight and all are of about the same length. But the forms have more or less variation according to the difference in the host plants.

The form of conidia on Picrasma is smaller, 28.8–34.4 × 15.6–18.0 μ, and the perithecia are smaller, 85.2–103.2 μ.

In the form parasitic on *Alnus hirsuta*, the original form of *Microsphaera Alni*, the perithecia are 94–126 μ in diameter, cells 15.6–19.2 × 10.8–14.4 μ in size; appendages aseptate or uniseptate,

pale brown colored toward the base or light brown colored under the septum when it has a septum, 8–11 in number, 91–115.2 μ in length, always 5–6 times dichotomously branched; asci oblong or subglobose, 3–5 in number, 40.8–55.6×36.0–46.8 μ; ascospores ellipsoidal, 5–8 in number, 16.8–24.0 × 10.8–12.8 μ.

In 1901, *Microsphaera japonica* was described by P. HENNINGS on the form on *Cornus macrophylla* (= *Cornus controversa*) which was collected by K. SHIRAI in Tokyo. The original description of the fungus coincides so exactly with the specimens collected in Hokkaido, that it could not be treated separately from *M. Alni*.

In the forms on *Schizandra chinensis* and *Akebia quinata*, the appendages of the perithecium have very ornate dichotomous branches.

In the form on *Castanea crenata*, the perithecia are large in diameter, 116–130 μ.

On *Cocculus trilobus*, besides *Microsphaera pseudo-Lonicerae*, the typical *Microsphaera Alni* was also found, probably for the first time, in Japan.

In the form on *Rhododendron macrocepalum* which was collected by T. ABE in Kyoto, Prov. Yamashiro, Oct. 25, 1933, the appendages are irregular in form, the ultimate branches are irregularly divided, and their apices are almost straight. But the writer found a small number of the normal form of *M. Alni* on the same leaves. This material seems to be the result of an abnormal growth.

Microsphaera calocladophora ATKINS.

(Pl. X, fig. 8)

Journ. Elisha Mitch. Sci. Soc. VII, p. 73, 1891; ELL. & EVERH. N. Amer Pyren. p. 29, 1892; SACC. Syll. Fung. XI, p. 253, 1895.

Syn. *Erysiphe densissima* SCHW. Syn. Fung. Am. Bot. p. 270, 1834.

Microsphaera densissima (not COOKE & PECK), ELL. & MART. Journ. Myc. I, p. 101, 1885; SACC. Syll. Fung. IX, p. 368, 1891.

Microsphaera Alni var. *calocladophora* SALM. Monogr. Erysiph. p. 153, 1900.

Microsphaera Alni var. *calocladophora* SCHLECHT. ex. in LAWR. Journ. Myc. XI, p. 106, 1905.

Amphigenous, mycelium persistent, effused over the surface of the leaves (mostly young leaves); perithecia gregarious, globose or

depressed-globose, 91–126 μ in diameter; cells 8.4–14.4 μ in width; appendages 7–14, hyaline or light brown colored toward the base, 84–112 μ long, aseptate, apex 4–6 times dichotomously branched, often trichotomously divided (in this case, branches have a main axis), apices of ultimate branches recurved; asci 3, ellipsoidal or subglobose, with or without short stalk, 42.0–52.8 × 32.6–39.6 μ; spores 7–8 in number, oblong or ellipsoidal, 15.6–17.4 × 10.8–12.0 μ.

Hab. On leaves and shoots of *Quercus alba* L. Hokkaido—Ishikari.
Distrib. Japan (Hokkaido) and North America.

Remarks. In 1834, SCHWEINITZ described two new species of Erysiphe parasitic on Quercus, one of them was named *Erysiphe densissima* SCHW., and the other *Erysiphe quercina* SCHW. In 1872, *E. densissima* was transferred to *Microsphaera densissima* by COOKE & PECK. But those specimens which were included in that species, belonged properly to *E. quercina*. In 1885, ELLIS and MARTIN noted for the first time on the often trichotomously branched characters of the appendages of *M. densissima*. In 1891, a new species parasitic on Quercus was recorded by ATKINSON under the name of *Microsphaera calocladophora*. In 1900, SALMON considered it as a variety of *M. Alni*.

In the present species,the appendages are often trichotomously branched in the first and second divisions, in which case the main axis is found running throughout. By this special form of the appendages the present species can be distinguished from the other species of Microsphaera.

Microsphaera alphitoides GRIFF. & MAUBL.

(Pl. X, figs. 9–11)

Bull. Soc. Myc. France, XXVIII, p. 100–103, 1912; ŠKORIĆ, Erysiph. Croat. p. 53, 1926; BLUMER, Mitt. Naturforsch. Gesellsch. Bern, p. 44, 1925. (Rev. App. Myc. V, p. 65, 1926).

Syn. *Microsphaera penicillata* LÉV. in SACC. Syll. Fung. I, p. 13 (p.p.), 1882.

Microsphaera quercina (not BURR.), GRIFF. Bull. Torr. Bot. Club, XXVI, p. 144, 1899; JØRST. Erysiph. Norway, p. 96, 1925.

Microsphaera Alni SALM. Monogr. Erysiph. p. 129 (p.p.), 1900, and Bull. Torr. Bot. Club, XXIX, p. 105 (p.p.), 1902; TAI & WEI,

Sinensia, III, p. 116 (p.p.), 1932. (SALM. Bull. Torr. Bot. Club, XXVII, p. 444 (p.p.), 1900, Ann. Myc. III, p. 250 (p.p.), 1905, and VI, p. 8 (p.p.), 1908; MATSUM. Ind. Plant. Jap. I, p. 156 (p.p.), 1904; SHIRAI, List, p. 215, 1905; IDETA, Jap. Phytopath. p. 205 (p.p.), 1911, and Jap. Phytopath. (Suppl. I), p. 211 (p.p.), 1923; I. MIYAKE, Bot. Mag. Tokyo, XXVII, p. 39, 1913, and XXVIII, p. 39 (p.p.), 1914; SYD. Ann. Myc. XI, p. 114 (p.p.), 1913; SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 61 (p.p.), 1914; SHIRAI & MIYAKE, List, p. 365 (p.p.), 1914; HARA, Dendropath. p. 11 (p.p.), 1923; SHIRAI & HARA, List, p. 215 (p.p.), 1927).

Microsphaera Alni f. sp. *quercina* NEGER, Naturwiss. Zeitschr. f. Forest- u. Landwirtsch. XIII, p. 3–6, 1915; KLIKA, Erysiph. Czechosl. p. 54 (p.p.), 1924.

Microsphaera Alni SALM. Forma *Quercus-glanduliferae* HARA, Journ. Forest. Assoc. Japan, Tokyo, CCCXCII, p. 64, 1915; TANAKA, Mycolog. XI, p. 82, 1919.

Oidium quercinum THÜM. var. *gemmiparum* FERR. Ann. Myc. VII, p. 69, 1909; SACC. Syl. Fung. XXII, p. 1249, 1913.

Oidium alphitoides GRIFF. & MAUBL. Bull. Soc. Myc. France, XXVI, p. 137, 1910.

Amphigenous, mycelium persistent on the upper surface of the leaves and subpersistent on the under surface, at first forming thin effused film and finally covering over the leaves with thick grayish white mycelial hyphae; matured conidia solitary, ellipsoidal or barrel-shaped, granulate, vacuolate, 30.0–36.0 × 16.8–23.0 μ; perithecia scattered or gregarious, 84–168 μ in diameter, globose or depressed-globose; cells 14.4–28.8 × 10.8–18.0 μ in size; appendages 9–27 in number, aseptate or uniseptate, usually hyaline or brown colored toward the base when it has one septum, 4–6 times dichotomously branched, frequently bifurcate at the basal or upper portion of the appendages, apex of the ultimate branches usually recurved, 84.0–154 μ in length; asci 5–16 in number, ovate or subglobose, with a short stalk, 46.8–72.0 × 36.0–48.0 μ; spores 5–8, usually 8, ellipsoidal or oblong, 15.6–24.0 × 9.6–14.4 μ.

Hab. On leaves and shoots of *Pasania Sieboldii* MAKINO (Shiinoki). Honshu—Suruga.

On *Quercus acutissima* CARR. (Kunugi). Honshu—Rikuchu, Rikuzen, Musashi, Etchu, Shinano. Kyushu—Higo. Korea—Keijo.

On *Quercus alba* L. Hokkaido—Ishikari.

On *Quercus crispula* BLUME (Mizunara). Hokkaido—Oshima, Shiribeshi, Iburi, Ishikari, Kushiro. Honshu—Rikuchu, Rikuzen, Uzen, Musashi, Echigo. Shikoku—Tosa. Kyushu—Higo.

On *Quercus dentata* THUNB. (Kashiwa). Hokkaido—Oshima, Shiribeshi, Iburi, Ishikari, Tokachi, Kushiro. Honshu—Mutsu, Inaba. Kyushu—Higo.

On *Quercus gilva* BLUME (Ichii-gashi). Kyushu—Higo, Ohsumi.

On *Quercus glauca* THUNB. (Aragashi). Honshu—Musashi, Suruga. Shikoku—Iyo.

On *Quercus mongolica* FISCH. (Karafuto-gashiwa). Saghalien—Sakaehama.

On *Quercus myrsinaefolia* BLUME (Shira-kashi). Honshu—Musashi.

On *Quercus phylliraeoides* A. GRAY (Ubame-gashi). Honshu—Musashi, Bitchu. Shikoku—Tosa.

On *Quercus Robur* L. Hokkaido—Ishikari.

On *Quercus serrata* THUNB. (Konara). Hokkaido—Ishikari. Honshu—Rikuchu, Rikuzen, Musashi, Echigo, Etchu, Kaga. Shikoku—Tosa.

On *Quercus stenophylla* MAKINO (Urajiro-gashi). Honshu—Musashi.

On *Quercus Vibreyana* FR. & SAV. (Kuro-kashi). Honshu—Musashi.

Distr. Japan (Saghalien, Hokkaido, Honshu, Shikoku, Kyushu, Formosa and Korea), Manchuria, China and Europe.

Remarks. The powdery mildew parasitic on Quercus in Europe and America was thought for a long time to be one and the same species. In 1910, GRIFFON and MAUBLANC published as *Oidium alphitoides* a powdery mildew on the leaves of Quercus in Europe, and in 1912, it was transferred to the genus Microsphaera following the discovery of its perithecia. It was found to be distinct from *Microsphaera quercina*, the American oak mildew. According to them, the conidia are ovate or barrel-shaped, obtuse at both ends, hyaline, guttulate, 25–35 × 14–19 μ and the perithecia larger in size while the number of appendages and their branches are more numerous, than in the case of *M. quercina*. The present author compared the Japanese specimens with the European (Sydow, Mycotheca Germanica No. 1531) and American specimens (United States Department of Agriculture, Bureau of Plant Industry, No's. 1516, 1517, 1518, 1519, 1521 and 64274). The Oidium of the Japanese specimens is almost like the European (*Oidium alphitoides*), and the barrel-shaped conidia were not seen in the American specimens. The matured Oidium-spores of the oak mildew are usually solitary, but sometimes they are produced in a chain of two or three as a result of environmental conditions. In this case, the terminal spore is ovate or ellipsoidal, and the second and third conidia are barrel-shaped in the Japanese and European forms, while in the American they are always cylindrical. On the character of the perithecia, the diameter of the

largest one is 168 μ in the Japanese specimens, and in the American 126 μ, the number of appendages reaches 27 in the former, and in the latter less than 20, but the writer can not recognize any difference in the apical branches, because the appendages of the perithecium of powdery mildew on Quercus are quite variable in shape. From these characters, one can infer that our fungus belongs to the European species.

In 1925, BLUMER (52) noted the difference between *Microsphaera Alni* and *M. alphitoides* based on the measurement of 100 perithecia of each. The average diameter of the perithecia of *Microsphaera* on the European oak is 131 μ; that of *Microsphaera Alni* on Alnus 98 μ; and *M. Alni* on Viburnum 93 μ. The corresponding number of appendages was 17, 10 to 12 and 6, respectively; therefore, the oak mildew could be distinguished from *Microsphaera Alni* and the name *M. alphitoides* should be adopted.

In 1915, HARA published *Microsphaera Alni* (WALLR.) SALM. form. *Quercus-glanduliferae* on *Quercus glandulifera*, giving for its differential character,—"appendages once branched dichotomously at about the middle. Other characters the same as in the type". This character of the appendages appears not only in the form on *Quercus serrata*, (= *Q. glandulifera*) but is also found in that on *Quercus crispula*.

In the form on *Quercus phylliraeoides* (Tokyo, Meguro, Nov. 13, 1922, S. ISHIYAMA), the appendages of the perithecium are short, 64.8–79.2 μ, and do not reach the diameter of the perithecium even in matured specimens.

Microsphaera Ligustri HOMMA, sp. nov.

(Pl. X, fig. 12)

Amphigena; mycelio epiphyllo persistente, hypophyllo evanido; peritheciis, gregariis 94–98 μ. diam., globosis v. globoso-depressis, cellulis 16.8–21.6 × 12.0–14.4; appendicibus 6–9, hyalinis v. deorsum pallido-brunneis, 112–133 μ longis, continuis v. 1–2-septatis, quater-quinquies dichotome ramosis, ramulis ultimis recurvatis; ascis 4 in quoque perithecio, subglobosis v. ovoideis, 51.6–58.8 × 36.0–50.4, 3–8-sporis; sporidiis ellipsoideis, 24.8–26.4 × 12.0–14.4.

Hab. On leaves of *Ligustrum ovalifolium* HASSK. (Ohba-ibota).
Hokkaido—Prov. Ishikari: Sapporo (Oct. 14, 1895, E. TOKUBUCHI, type).
Distrib. Japan (Hokkaido).

Remarks. The form on *Ligustrum ovalifolium* was included under *Microsphaera Alni* by SALMON in his monograph on the Erysiphaceae. He said, "the form on *Ligustrum medium* has often quite colorless appendages and the compact apical branching characteristic of *M. Alni*; in many perithecia, however, the apex of some of the appendages forks widely, the primary branches being sometimes quite long. Not infrequently, also, the appendages are colored brown near the base, and a few perithecia were observed in which the color, although faint, reached to the base of the apical branching". In the appendages of the present species there are two forms, in one of which the manner of the branching resembles that of *M. Alni*, while in another the primary branches are more or less recurved as in that of *M. divaricata*. Besides, in some the primary branches divide frequently at about the middle or near the base. In these characters, the present species is readily distinguished from *M. Alni*. In *M. divaricata*, the appendages do not bifurcate at the middle or near the base and are shorter, the cells of the perithecial wall are smaller, and the asci and ascospores are also smaller than in *M. Ligustri*. The present species must be placed between *M. Alni* and *M. divaricata*, and should better be treated as a new species.

Microsphaera divaricata (WALLR.) LÉV.

(Pl. X, fig. 13)

Ann. Sci. Nat. III, 15, p. 155, 1851; KICKX, Fl. Crypt. Fland. I, p. 378, 1867; COOKE & PECK, Journ. Bot. I, p. 12, 1872; SACC. Syll. Fung. I, p. 11, 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 38, 1884; SCHRÖT. in COHN'S Krypt. Fl. Schles. III, p. 242, 1893; JACZEW. Bull. l'Herb. Boiss. IV, p. 749, 1896; LIND, Danish Fung. p. 163, 1913; JØRST. Erysiph. Norway, p. 98, 1925. (FUCK. Symb. Myc. p. 81, 1869–70; HARA, Dendropath. p. 14, 1923).

Syn. *Alphitomorpha divaricata* WALLR. Verhandl. Nat. Freunde, I, p. 39, 1819.

Erysiphe penicillata var. *Rhamni-fragulae* FR. Syst. Myc. III, p. 244, 1829.

Erysiphe divaricata LK. in RABENH. Deutschl. Krypt. Fl. I, p. 236, 1844.

Microsphaera Alni SALM. var. *divaricata* SALM. Monogr. Erysiph. p. 146, 1900, and Bull. Torr. Bot. Club, XXIX, p. 108, 1902; KLIKA,

Erysiph. Czechosl. p. 53, 1924. (SALM. Ann. Myc. VI, p. 9, 1908; SHIRAI & MIYAKE, List, p. 365, 1917; SHIRAI & HARA, List, p. 216, 1927).

Amphigenous, mostly epiphyllous, mycelium persistent, covering the upper surface of the leaves with thin effused film; perithecia small, gregarious or scattered, 77–98 μ in diameter, globose or depressed-globose; cells 16.8–18.0 × 9.6–13.2 μ; appendages 5–9 in number, aseptate or uniseptate, hyaline or pale brown colored at the base, becoming thick-walled toward the base, 91.0–126.0 μ in length, dichotomously branched 5–6 times, apex of the ultimate branches recurved, primary and secondary branches recurved and forked very widely; asci 4–6 in number, rhombic subglobose, with or without stalk, 51.2–60.0 × 42.0–50.4 μ; spores 4–8, oblong to ellipsoidal, 19.2–24.0 × 12.0–16.8 μ.

Hab. On leaves of *Palura paniculata* NAKAI var. *pilosa* NAKAI (Sawafutagi). Honshu—Musashi.

Distrib. Japan (Honshu) and Europe.

Remarks. In 1851, this species was transferred to *Microsphaera divaricata* by LÉVEILLÉ from *Alphitomorpha divaricata* WALLR., and in 1900, SALMON treated it as a variety of *M. Alni*.

The present species can be distinguished from *M. Alni* by the longer and very widely bifurcate character of the primary and secondary branches of the appendages.

The first record of this species in Japan is on the form on *Berberis vulgaris* (Morioka, Prov. Rikuchu, Oct. 11, 1906, Coll. K. OKUMURA). Unfortunately, we could not see the specimen on that host, but the form on *Palura paniculata* var. *pilosa* has been found as a new host in this country. This form is evidently of the same type, although the appendages of the perithecium are shorter than those of the European specimens.

Microsphaera Coryli HOMMA, sp. nov.

(Pl. X, fig. 14)

Amphigena, etiam in surculis; mycelio effuso persistente; peritheciis gregariis, 122–140 μ. diam., globosis v. globoso-depressis, cellulis 8.4–12.0 μ. diam.; appendicibus 9–14, flexuosis, flaccidis, deorsum brunneis, 196–238 μ. longis, 1–5-septatis, ter-quinquies dichotome

ramosis, ramulis ultimis recurvatis v. erectis; ascis 5 in quoque perithecio, globosis v. subglobosis, brevissime pedicellatis, 45.6–51.8 × 34.8–40.8, 6-sporis; sporidiis ellipsoideis v. oblongis, 16.4–18.0 × 9.6–10.8; conidiis maturis solitariis, ellipsoideis, granulatis, 34.8–45.6 × 21.6–36.

Hab. On leaves of *Corylus heterophylla* FISCH. (Oh-hashibami).

Honshu—Prov. Rikuchu: Mt. Himekamiyama (June 30, 1907, G. YAMADA); Tamayama-mura (Oct. 10, 1909, G. YAMADA), Morioka (Oct. 1, 1916, G. YAMADA).

On *Corylus heterophylla* FISCH. var. *japonica* KOIDZ. (Hashibami). Honshu—Prov. Musashi: Kanagawa (Oct. 26, 1904, N. NAMBU).

On *Corylus mandshurica* MAXIM. (Ohba-tsuno-hashibami). Hokkaido—Prov. Shiribeshi: Takashima (Aug. 7, 1894, E. TOKUBUCHI, type); Otaru (Aug. 1897, G. YAMADA; Sept. 17, 1897, K. MIYABE; July 30, 1905, K. MIYABE); Temiya (Oct. 12, 1903, K. MIYABE); Akaiwa (Aug. 7, 1924, Oid. Y. HOMMA). Prov. Ishikari: Sapporo (Aug. 1900, M. ISHIDA); Mt. Moiwa (June 22, 1924, Oid. Y. HOMMA; July 31, 1924, Oid. H. TAKASUGI; Aug. 29, 1924, Y. HOMMA; May 28, 1925, Oid. Y. HOMMA).

On *Corylus Sieboldiana* BL. (Tsuno-hashibami). Honshu—Prov. Mutsu: Mt. Hakkoda (Aug. 26, 1897, N. HIRATSUKA); Hirosaki (Sept. 4, 1898, N. HIRATSUKA). Prov. Rikuchu; Morioka (Sept. 23, 1904, G. YAMADA & K. SAWADA); Tamayama-mura (Oct. 28, 1906, K. SAWADA). Prov. Shimozuke: Nikko (July 29, 1907, Oid. S. KUSANO). Prov. Echigo: Shobu, Oshima-mura (July 28, 1931, K. ISHIZUKA).

Distrib. Japan (Hokkaido and Honshu).

Remarks. In 1900, SALMON gave the following description for this species in his remarks on *M. Alni*,—"The appendages of most perithecia are rather long, often twice the diameter of the perithecium, and are multiseptate and uniformly colored brown to the commencement of the special branching. The apical branching is rather irregular, the primary branches being frequently long. Nevertheless, even in this form with usually strongly colored appendages, we get occasionally colorless appendages, and a small compact apex branched in the normal manner for *M. Alni*. The wide branching of some of the appendages of these two forms tends to connect them with the var. *divaricata* while the quite sporadic appearance of colored appendages shows that, in *M. Alni*, no value can be attached to this character". As indicated in the above note, the appendages are rather long, reaching 238 μ in length, having 1–5 septa. In the apical branching there are two types, in one of them it resembles that

of *M. Alni*, and in the other it is similar to that of *M. Yamadai*. In this species, the appendages can easily be distinguished from those of *M. Alni*, and the diameter of the perithecium is larger than that in the latter species.

On the other hand, this species could not be included under *M. Yamadai*, because its appendages are rather longer and gradually become narrowed toward the apex, and the diameter of the perithecium is larger.

Microsphaera Yamadai (SALM.) SYD.

(Pl. X, figs. 15, 16)

Ann. Myc. XII, p. 160, 1914. (HARA, Dendropath. p. 12, 1923; SHIRAI & HARA, List, p. 217, 1927).

Syn. *Microsphaera Alni*, form. SALM. Ann. Myc. III, p. 246, 1905.

Microsphaera Alni SALM. var. *Yamadai* SALM. Ann. Myc. VI, p. 3, 1908. (SALM. Ann. Myc. VI, p. 9, 1908; SHIRAI & MIYAKE, List, p. 365, 1917).

Microsphaera penicillata LÉV. var. *Yamadai* SACC. & TROT. in SACC. Syll. Fung. XXII, p. 24, 1913. (SHIRAI & MIYAKE, List, p. 367, 1917).

Amphigenous, mostly hypophyllous, mycelium evanescent, disappearing when the perithecia are produced on the leaves; perithecia scattered or subgregarious, 91–126 μ in diameter; cells 10.8–14.4 μ in width; appendages 5–14 in number, aseptate or 1–2-septate, dark brown colored toward the base, 84–175 μ in length, frequently flaccid, flexuous, primary branches long, dichotomously branched 2 or 3 times, usually 3, apex of the ultimate branches recurved and twisted; asci 4–7, usually 6, oblong or ovate, with a short stalk, 43.2–62.4 × 33.6–43.2 μ; spores 4–8 in number, oblong or ellipsoidal, 16.8–21.6 × 8.4–13.2 μ in size.

Hab. On leaves of *Juglans Sieboldiana* MAXIM. (Oni-gurumi). Honshu—Rikuchu.

On *Hovenia dulcis* THUNB. var. *glabra* MAKINO (Kemponashi). Honshu—Mutsu, Rikuchu, Musashi.

Distrib. Japan (Honshu).

Remarks. This fungus was at first included in *M. Alni* by SALMON. He stated as follows: "this form has small perithecia,

with few and little-branched appendages; the primary branches are often rather long, and the branches of the high order are short, and often twisted in different planes". Later he transferred it to a new variety of *M. Alni*. On the difference from *M. Alni*, he noted that "the variety is characterized by the little-branched apex of the appendages, which is only once or twice or rarely three times dichotomously divided. As a rule, the branches of the first order are longer than those of higher orders which are often twisted in different planes".

In 1914, this variety was elevated to specific rank by H. and P. SYDOW. After careful observations, the present author has come to a concurrent opinion. It is distinguished from *M. Alni* by the following characters. The perithecia are smaller, the appendages are frequently flaccid and flexuous, primary branches are longer, and 2–3 times dichotomously branched, and the ultimate branches often twisted in different planes.

Microsphaera Euphorbiae (PECK) BERK. & CURT.

(Pl. X, fig. 17)

Grevillea, IV, p. 160, 1876; SACC. Syll. Fung. I, p. 13, 1882; BURR. & EARLE, Bull. Ill. Stat. Lab. Nat. Hist. II, p. 418, 1887; ELL. & EVERH. N. Amer. Pyren. p. 26, 1892; SALM. Monogr. Erysiph. p. 164, 1900. (TRACY and GALLOW. Journ. Myc. IV, p. 35, 1888; SALM. Bull. Torr. Bot. Club, XXIX, p. 109, 1902, and Ann. Myc. III, p. 250, 1905; SHIRAI & MIYAKE, List, p. 365, 1917; SHIRAI & HARA, List, p. 216, 1927).

Syn. *Erysiphe Euphorbiae* PECK, Reg. Rep. XXVI, p. 80, 1874; SACC. Syll. Fung. I, p. 18, 1882.

Microsphaera Securinegae TAI & WEI, Sinensia, III, p. 120, 1932.

Amphigenous, mycelium subpersistent, forming thin effused film; perithecia scattered or subgregarious, depressed-globose, 91–112 μ in diameter; cells 15.6–16.8 × 14.4–15.2 μ in size; appendages 10–21 in number, hyaline, aseptate, narrowed, thin-walled, about 336–434 μ in length, frequently angularly bent, 3–4 times dichotomously divided, primary branches are long, branches of the higher order are short and twisted, apex of the ultimate branches recurved; asci 4–6, oblong or ovate, 38.4–46.8 × 25.2–36.0 μ in size; spores 5–7 in number, elongate-ellipsoidal, 19.2–20.0 × 9.6–10.8 μ.

Hab. On leaves of *Securinega fluggeoides* MUELL. ARG. (Hitotsuba-hagi). Honshu—Musashi.

Distrib. Japan (Honshu), China, Middle Asia and North America.

Remarks. The present species is found only on *Securinega fluggeoides*, and has not yet been collected on other plants of *Euphorbiaceae* in this country.

Microsphaera Abeliae HOMMA, sp. nov.

(Pl. X, fig. 18)

Epiphylla; mycelio effuso subpersistente; peritheciis sparsis, globosis v. globoso-depressis, 72–108 μ. diam., cellulis 19.2–26.4 × 14.4–16.8; appendicibus 5–7, 182–308 μ. longis, flaccidis, flexuosis, continuis v. raro 1–5-septatis, pallido-brunneis, deorsum brunneis, bis-quinquies dichotome ramosis, ramulis ultimis irregulariter partitis, rectis; ascis 2–5 in quoque perithecio, ellipsoideis, 48.0–58.8× 31.2–46.8, 6-sporis; sporidiis oblongis, 18.0–21.6×9.6–12.

Hab. On leaves of *Abelia spathulata* SIEB. & ZUCC. (Tsukubane-utsugi). Honshu—Prov. Echigo: Mt. Ijimino (Oct. 10, 1924, Y. HOMMA, type; Aug. 25, 1926, Y. HOMMA); Mt. Kaji (Aug. 29, 1925, Y. HOMMA); Senami (Aug. 23, 1927, Y. HOMMA).

Distrib. Japan (Honshu) .

Remarks. The present species is closely related to *Microsphaera pseudo-Lonicerae* and *M. divaricata*. It is distinguished from *M. pseudo-Lonicerae* by the smaller size of the perithecium, the larger size of its outer wall cells and also by the longer appendages. From *M. divaricata*, the present fungus differs by the straight apex of the ultimate branches, and by the smaller size of asci and ascospores.

Compared with *M. Euphorbiae*, it has longer appendages and smaller asci.

Microsphaera Lonicerae (DC.) WINT.

in RABENH. Krypt. Fl. Deutschl. I, 2, p. 36, 1884; SCHRÖT. in COHN's Krypt. Fl. Schles. III, p. 243, 1893; JACZ. Bull. l'Herb. Boiss. IV, p. 747, 1896; OUDEM. Rév. Champ. Pays-Bas, II, p. 89, 1897; JØRST. Erysiph. Norway, p. 94, 1925; ŠKORIĆ, Erysiph. Croat. p. 52, 1926. (RANOJ. Ann. Myc. VIII, p. 357, 1910).

Syn. *Erysiphe lonicerae* DC. Fl. Fr. VI, p. 107, 1815; TULASNE, Selecta Fung. Carpolog. I, p. 205, 1861.

Erysiphe penicillata var. *lonicerae* FR. Syst. Myc. III, p. 244, 1829.

Erysiphe penicillata var. *caprifoliacearum* RABENH. Deutschl. Krypt. Fl. I, p. 236, 1844.

Microsphaera Ehrenbergii LÉV. Ann. Sci. Nat. III, 15, p. 155, (*Calocladia*) 1851; SACC. Syll. Fung. I, p. 14, 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 39, 1884; SCHRÖT. in COHN's Krypt. Fl. Schles. III, p. 244, 1893; JACZ. Bull. l'Herb. Boiss. IV, p. 748, 1896; OUDEM. Rév. Champ. Pays-Bas, II, p. 93, 1897.

Microsphaera Alni var. *lonicerae* SALM. Monogr. Erysiph. p. 142, 1900, and Bull. Torr. Bot. Club, XXIX, p. 107, 1902; KLIKA, Erysiph. Czechosl. p. 53, 1924.

Amphigenous, also on shoots, mycelium subpersistent or evanescent, thin effused film; perithecia gregarious, globose, blackish-brown in color, 80–105 μ in diameter; cells obscure, 16.8–21.6 × 14.4–16.8 μ in size; appendages 10–23 in number, straight or bent, 126–140 μ in length, aseptate, uni- or rarely bi-septate, hyaline or brown colored under the septum, dichotomously branched 4 or 5 times, tips of the ultimate branches always straight, rarely recurved; asci 3–4, subglobose, not stalked, 43.2–57.6 × 36.0–45.6 μ; spores 4–6, oblong or ellipsoidal, 21.6–24.0 × 14.4–15.6 μ in size.

Hab. On leaves and shoots of *Lonicera japonica* THUNB. (Suikazura). Honshu—Rikuchu.

Distrib. Japan (Honshu) and Europe.

Remarks. In the present species, the ultimate branches appear looser than those of *M. Alni*, for the tips of the branches are straight, although some recurved are seen here and there. Most of the specimens on Lonicera which were collected in this country belong to the typical *M. Alni*, from which the form on *L. japonica* is readily distinguished.

Microsphaera pseudo-Lonicerae (SALM.) HOMMA, comb. nov.

(Pl. X, fig. 19)

Syn. *Microsphaera Alni* (WALLR.) SALM. var. *pseudo-Lonicerae* SALM. Ann. Myc. VI, p. 4, 1908; TAI & WEI, Sinensia, III, p. 119, 1932. (SHIRAI & MIYAKE, List, p. 365, 1917; SHIRAI & HARA, List, p. 216, 1927).

Microsphaera penicillata (WALLR.) LÉV. var. *pseudo-Lonicerae* SACC. & TROT. in SACC. Syll. Fung. XXII, p. 24, 1913. (SHIRAI & MIYAKE, List, p. 367, 1917; IDETA, Jap. Phytopath. (Suppl. I), p. 213, 1923).

Amphigenous, mycelium persistent, forming irregular white patches on the upper surface of the leaves; perithecia gregarious or subgregarious, 98–126 μ in diameter, globose or depressed-globose; cells 9.6–16.8 μ in width; appendages 3–13 in number, usually 10, hyaline or brown colored toward the base, short, 124–161 μ in length, *thin-walled, aseptate or uni-septate, dichotomously branched 5 or 6 times, tips of the ultimate branches straight*; asci 4–6 in number, oval or ovate, with or without stalk, 46.4–52.8 × 38.4–42.0 μ; spores 5–6, usually 6, ellipsoidal or ovate, 19.2 × 10.8–14.4 μ.

Hab. On leaves of *Cocculus trilobus* DC. (Ao-tsuzura-fuji). Honshu—Mutsu, Echigo, Etchu. Shikoku—Tosa.

Distrib. Japan (Honshu and Shikoku) and China.

Remarks. In 1908, SALMON described a powdery mildew on *Cocculus trilobus* which was collected by YOSHINAGA at Misatomura, Prov. Tosa, under the name of *Microsphaera Alni* var. *pseudo-Lonicerae*, from the fact that its appendages closely resemble those of *M. Alni* var. *Lonicerae*.

In the present species, the ultimate branches are straight, and are usually of unequal length. By these characters it is distinguished from *M. Alni*.

Microsphaera Berberidis (DC.) LÉV.

(Pl. X, fig. 20)

Ann. Sci. Nat. III, 15, p. 159, 1851; KICKX, Fl. Crypt. Fland. I, p. 379, 1867; COOKE, Handb. Brit. Fung. II, p. 649, 1871; SACC. Syll. Fung. I, p. 13, 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 36, 1884; SCHRÖT. in COHN's Krypt. Fl. Schles. III, p. 243, 1893; OUDEM. Rév. Champ. Pays-Bas, II, p. 92, 1897; JACZEW. Bull. l'Herb. Boiss. IV, p. 746, 1898; MAGNUS, Erysiph. Tirol. p. 20, 1898; SALM. Monogr. Erysiph. p. 123, 1900, and Bull. Torr. Bot. Club, XXIX, p. 103, 1902; NEGER, Krypt. d. Mark Brand. VII, p. 128, 1905; LIND, Danish Fung. p. 163, 1913; KLIKA, Erysiph. Czechosl. p. 57, 1924; JØRST. Erysiph. Norway, p. 93, 1925; ŠKORIĆ, Erysiph. Croat. p. 54, 1926. (FUCK. Symb. Myc. p. 82, 1869–70; SALM. Bull. Torr. Bot.

Club, XXVII, p. 444, 1900; MATSUM. Ind. Plant. Jap. I, p. 154, 1904; SHIRAI, List, p. 55, 1905; RANOJ. Ann. Myc. VIII, p. 357, 1910; IDETA, Jap. Phytopath. p. 205, 1911, and Jap. Phytopath. (Suppl. I), p. 212, 1923; I. MIYAKE, Bot. Mag. Tokyo, XXVII, p. 39, 1913; SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 64, 1914; SHIRAI & MIYAKE, List, p. 365, 1917; HARA, Dendropath. p. 14, 1923; SHIRAI & HARA, List, p. 216, 1927; MIURA, Fl. Manchuria and East Mongolia, III, p. 138, 1927).

Syn. *Erysiphe Berberidis* DC. Fl. Fr. II, p. 275, 1805; MÉRAT, Nouv. Fl. Paris, p. 75 (p.p.), 1837, and Syn. Nouv. Fl. Paris, p. 84 (p.p.), 1837; DE BARY, Beitr. Morph. Phys. Pilz. I, xiii, p. 51, 1870; TULASNE, Selecta Fung. Carpolog. I. p. 204, 1861.

Erysiphe penicillata LK. var. *Berberidis* LK. in WILLD. Sp. Pl. VI, p. 114, 1824; RABENH. Deutschl. Krypt. Fl. I, p. 236, 1844.

Erysiphe penicillata var. *Berberidis* FR. Syst. Myc. III, p. 244, 1829.

Podosphaera Berberidis LÉV. in QUÉL. Champ. Jur. Vosg. p. 534, 1875.

Amphigenous, mycelium persistent, at first forming irregular white patches on the surface of the leaves, and finally covering over the whole surface; matured conidia solitary, oblong or cylindrical-oblong in shape, vacuolate, granulate, 27.6–39.6 × 13.2–14.4 μ in size; perithecia gregarious or slightly scattered, globose or depressed-globose, 98–119 μ in diameter; cells 9.6–14.4 μ in width; appendages 9–13 in number, light brown colored at the base, aseptate or uniseptate, 126–140 μ in length, dichotomously branched 4–6 times, frequently branches of the higher order more or less irregularly divided, and the apex of the ultimate branches always straight, thin-walled throughout; asci 4–7 in number, ellipsoidal or subglobose, short-stalked, 46.4–49.2 × 32.4–36.0 μ; spores 3–5, elongate-ovate or ellipsoidal, 18.0–21.6 × 9.6–14.4 μ.

Hab. On leaves and shoots of *Berberis amurensis* RUPR. (Ohbamegi). Hokkaido—Ishikari. Honshu—Rikuchu.

On *Berberis Regeliana* KOEHNE (Hiroha-hebinoborazu). Hokkaido—Oshima, Shiribeshi, Ishikari, Hidaka. Honshu—Rikuchu.

On *Berberis Thunbergii* DC. var. *Maximowiczii* FRANCH. & SAV. (Megi). Hokkaido—Ishikari. Honshu—Musashi.

Distrib. Japan (Hokkaido and Honshu) and Europe.

Remarks. This fungus appears on both surfaces of the leaves and shoots, frequently covering the whole surface of the host plant. At the time when the perithecia are abundantly produced, the surface of the host plants becomes changed to gray color.

According to SCHRÖTER's description, the appendages are said to reach 400 μ in length, but we could not find such a long one amongst our specimens.

Microsphaera Grossulariae (WALLR.) LÉV.

(Pl. X, fig. 21)

Ann. Sci. Nat. III, 15, p. 160, 1851; KICKX, Fl. Crypt. Fland. I, p. 380, 1867; COOKE, Handb. Brit. Fung. II, p. 649, 1871; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 37, 1884; ELL. & EVERH. N. Amer. Pyren. p. 24, 1892; SCHRÖT. in COHN's Krypt. Fl. Schles. III, p. 244, 1893; JACZEW. Bull. l'Herb. Bois. IV, p. 747, 1896; OUDEM. Rév. Champ. Pays-Bas, II, p. 90, 1897; PRILL. Malad. Pl. Agr. II, p. 31, 1897; MAGNUS, Erysiph. Tirol. p. 20, 1898; SALM. Monogr. Erysiph. p. 157, 1900, and Bull. Torr. Bot. Club, XXIX, p. 108, 1902; Neger, Krypt. d. Mark Brand. VII, p. 128, 1905; LIND, Danish Fung. p. 163, 1913; KLIKA, Erysiph. Czechosl. p. 57, 1924; JØRST. Erysiph. Norway, p. 92, 1925; ŠKORIĆ, Erysiph. Croat. p. 54, 1926. (FUCK. Symb. Myc. p. 81, 1869–70; SALM. Bull. Torr. Bot. Club, XXVII, p. 445, 1900, Ann. Myc. III, p. 250, 1905, and VI, p. 9, 1908; MATSUM. Ind. Plant. Jap. I, p. 154, 1904; SHIRAI, List, p. 55, 1905; IDETA, Jap. Phytopath. p. 206, 1911, and Jap. Phytopath. (Suppl. I), p. 213, 1923; SYD. Ann. Myc. XI, p. 114, 1913; SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 59, 1914; SHIRAI & MIYAKE, List, p. 367, 1917; HARA, Dendropath. p. 14, 1923; SHIRAI & HARA, List, p. 216, 1927).

Syn. *Alphitomorpha penicillata* var. *Grossulariae* WALLR. Berl. Ges. Nat. Freund. Verh. I, p. 40, 1819.

Erysibe penicillata var. *Grossulariae* LK. in WILLD. Sp. Pl. VI, p. 114, 1824; RABENH. Deutschl. Krypt. Fl. I, p. 236, 1844.

Erysiphe penicillata var. *Grossulariae* FR. Syst. Myc. III, p. 224, 1829.

Erysiphe Grossulariae (LÉV.) DE BARY, Beit. Morph. Phys. Pilz. I, xiii, p. 52, 1870.

Microsphaera Van-Bruntiana GERARD, Bull. Torr. Bot. Club, VI, p. 31, 1875; SACC. Syll. Fung. I, p. 14, 1882.

Podosphaera Grossulariae (LÉV.) QUÉL. Champ. Jur. Vosg. p. 534, 1875.

Microsphaera sambucicola P. HENN. in ENGL. Bot. Jahrb. XXIX, p. 148, 1901. (SHIRAI, List, p. 55, 1905; SHIRAI & MIYAKE, List, p. 367, 1917).

Amphigenous, mostly hypophyllous, also on shoots, mycelium evanescent or subpersistent, forming thinly effused film; matured conidia solitary, oblong or ellipsoidal, vacuolate, granulate, 30.0–34.8 × 16.8–18.0 μ; perithecia scattered, sometimes gregarious, 108–130 μ in diameter; cells 9.6–12.0 μ; appendages 12–22 in number, aseptate or 1-septate, brown colored at the base, 98–136 μ in length, 4–5 times deeply bifurcate, apex of the ultimate branches straight; asci 4–7 in number, ovate to ellipsoidal, stalked, 50.4–66.0 × 31.2–43.2 μ in size; spores 4–5, oblong, ellipsoidal or ovate, 15.0–24.0 × 10.8–13.2 μ, rarely 12.0–7.2 μ in size.

Hab. On leaves and shoots of *Sambucus Buergeriana* BLUME var. *Miquelii* NAKAI (Yezo-niwatoko). Saghalien—Kaizuka-mura. Hokkaido—Iburi, Ishikari, Kushiro. Honshu—Rikuchu, Rikuzen, Musashi, Shimozuke.

On *Sambucus Sieboldiana* BLUME var. *typica* NAKAI (Niwatoko). Honshu—Rikuchu, Ugo, Musashi, Shimozuke, Echigo, Yamashiro, Inaba.

Distrib. Japan (Saghalien, Hokkaido, Honshu and Formosa), Europe and New Zealand.

Remarks. In 1901, P. HENNINGS described a new species of Microsphaera parasitic on *Sambucus racemosa* (coll. S. KUSANO, in Tokyo) under the name of *Microsphaera sambucicola* P. HENN. According to his remarks it is distinguished from *M. Grossulariae* by the smaller number of asci, the shorter appendages, and the larger ascospores. Fortunately, the writer has examined the co-type specimen of *M. sambucicola,* and also the several specimens which were identified by SALMON as *M. Grossulariae.* Moreover, we have examined numerous specimens of the form on Sambucus collected in the different parts in this country. No remarkable differences could be found between them.

The present species is closely related to *Microsphaera Berberidis* and *M. diffusa;* but it is distinguished from both of them by the more deeply bifurcate character of the apical branches of the appendages, by the digitate mode of branching, and also by the shorter length of the primary branches.

Microsphaera diffusa COOKE & PECK

(Pl. X, fig. 22)

Journ. Bot. I, p. 13, 1872; SACC. Syll. Fung. I, p. 12, 1882; BURR. & EARLE, Bull. Ill. Stat. Lab. Nat. Hist. II, p. 416, 1887; ELL. & EVERH. N. Amer. Pyren. p. 24, 1892; SALM. Monogr. Erysiph. p. 161, 1900. (PAMM. Journ. Myc. IV, p. 38, 1888; TRACY & GALLOW. Journ. Myc. IV, p. 35, 1888; SALM. Ann. Myc. VI, p. 9, 1908; LAWR., Journ. Myc. XI, p. 106, 1905; SHIRAI & MIYAKE, List, p. 365, 1917; HARA, Dendropath. p. 14, 1923; SHIRAI & HARA, List, p. 216, 1927).

Amphigenous, mostly epiphyllous, mycelium evanescent, thinly effused in cobweb-like fashion; matured conidia solitary, globose or subglobose, vacuolate, granulate, 29.6–31.2 × 21.6–25.2 μ; perithecia scattered, globose or depressed-globose, 105–126 μ in diameter; cells 12.0–14.4 μ in width; appendages 10–14 in number, hyaline or light brown colored toward the base, 140–180 μ in length, sometimes angularly bent, aseptate or uni-septate, dichotomously or subdichotomously branched 4 or 5 times, branches of the higher orders irregularly bifurcate and subnodulose, tips of the ultimate branches cylindrical or subclavate and straight; asci 3–8 in number, subglobose or obovate, short-stalked, 44.4–50.4 × 33.0–40.0 μ; spores 4 or 5, oblong or ellipsoidal, 18.0–21.6 × 8.4–10.8 μ in size.

Hab. On leaves of *Magnolia obovata* THUNB. (Hoonoki). Hokkaido—Oshima, Ishikari. Honshu—Rikuchu, Musashi.

Distrib. Japan (Hokkaido and Honshu) and North America.

Remarks. The present species can easily be distinguished from the related species by the characteristic mode of branching of the appendages. They are angularly bent at about the middle portion, the branches of the higher orders are irregularly branched, and the ultimate branches are often arranged in different planes and are subnodulose, cylindrical or subclavate.

This species resembles *Microsphaera Grossulariae*, but the appendages are longer and the apex of the ultimate branches is usually broader.

SALMON noted that the appendages are widely variable in number (4–30), but in the form which has been collected in Japan, they are 10–14 in number.

Microsphaera Bäumleri P. MAGNUS

(Pl. XI, figs. 1, 2)

Bericht. Deutsch. Bot. Gesell. XVII, p. 148, 1899; SALM. Monogr. Erysiph. p. 170, 1900, and Bull. Torr. Bot. Club, XXIX, p. 109, 1902. (HOMMA, Sapporo, Nat. Hist. Soc. XI, p. 171, 1930).

Syn. *Microsphaera Marchica* P. MAGN. Bericht. Deutsch. Bot. Gesell. XVII, p. 149, 1899.

Erysiphe Polygoni DC. in SALM. Bull. Torr. Bot. Club, XXVII, p. 443 (p.p.), 1900.

Trichocladia Bäumleri (MAGNUS) NEGER, Krypt. d. Mark Brand. VII, p. 123, 1905; KLIKA, Erysiph. Czechosl. p. 61, 1924; ŠKORIĆ, Erysiph. Croat. p. 50, 1926.

Microsphaera Polygoni (DC.) SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 56 (p.p.), 1914. (SHIRAI & MIYAKE, List, p. 225 (p.p.), 1917; SHIRAI & HARA, List, p. 217 (p.p.), 1927).

Amphigenous, mostly hypophyllous, also on stems, mycelium subpersistent; matured conidia solitary, elongate-ellipsoidal or cylindrical, vacuolate, granulate, 31.2–37.2 × 16.8–19.2 μ; perithecia subgregarious, globose or depressed-globose, 96–140 μ in diameter; cells 9.6–14.4 × 8.4–12.0 μ in size; appendages 8–20 in number, flaccid and more or less flexuous, aseptate or uni-septate, hyaline or brown colored under the septum, about 266–462 μ in length, simple or dichotomously branched 2 or 3 times, apex of the ultimate branches straight; asci 5–8 in number, subglobose or ovate, stalked, 51.6–67.2 × 31.2–40.8 μ; spores 3–5 in number, oblong, 15.6–24.0 × 9.6–14.0 μ.

Hab. On leaves of *Robinia pseudacacia* L. (Hari-enju). Hokkaido—Ishikari.

On *Vicia Cracca* L. var. *japonica* MIQ. (Kusa-fuji). Saghalien—Rutaka, Pupunii, Alexandrowsk, Akashiki, Rakuma. Hokkaido—Oshima, Shiribeshi, Iburi, Ishikari, Kitami, Hitaka. Honshu—Mutsu, Uzen, Musashi, Echigo.

On *Vicia japonica* A. GRAY (Hiroha-kusafuji). Hokkaido—Shiribeshi. Honshu—Mutsu.

On *Vicia nipponica* MATSUM. (Yotsuba-hagi). Honshu—Shimozuke.

Distrib. Japan (Saghalien, Hokkaido, Honshu and Formosa), Manchuria and Europe.

Remarks. Up to the present time, the form on *Vicia Cracca* has been included in *Erysiphe Polygoni*. While examining the numerous specimens parasitic on Leguminosae, the writer found that

the form on *Vicia Cracca* has appendages sometimes dichotomously branched at the apex when entirely matured. Also, it was observed that the appendages of this species take a much longer time than in the case of the related species to complete their growth. In the matured materials, about one half of the appendages are dichotomously branched. In the immatured materials, the appendages are always simple, and in this case they can not be distinguished from those of Erysiphe. Because of the characters of the appendages, the present species belongs evidently to Microsphaera being related to *M. Alni* var. *ludens* and *M. Astragali.* In the former, the appendages are more ornate, and in the latter, the primary branches of the appendages are rather widely branched.

In 1899, P. HENNINGS recorded two species of *Microsphaera Bäumleri* (on *Vicia sylvatica*) and *M. Marchica* (on *Vicia cassubica*). Concerning *M. Marchica,* the author is rather inclined to consider it as a form of the immature stages of *M. Bäumleri.*

In the form on *Vicia Cracca,* the appendages are long, flaccid and more or less flexuous, the apical branches are irregularly branched dichotomously 2 or 3 times when matured, and the apex of the ultimate branches is straight.

In the form on *Robinia pseudacacia,* the apex of the appendages is very rarely twice dichotomously branched which mode of branching is similar to that in the form on *Vicia Cracca,* besides other characters being the same.

Microspheera Viciae-unijugae HOMMA, sp. nov.

(Pl. XI, fig. 3)

Syn. *Erysiphe Polygoni* DC. in SALM. Bull. Torr. Bot. Club, XXVII, p. 443 (p.p.), 1900, Ann. Myc. III, p. 249 (p.p.), 1905, and VI, p. 8 (p.p.), 1908.

Microsphaera Polygoni (DC.) SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 56 (p.p.), 1914. (SHIRAI & MIYAKE, List, p. 225 (p.p.), 1917; SHIRAI & HARA, List, p. 217 (p.p.), 1927; MIURA, Fl. Manchuria and East Mongolia, III, p. 137 (p.p.), 1927).

Amphigena; mycelio effuso persistente; peritheciis sparsis v. subgregariis, globosis v. globoso-depressis, 98–133 μ. diam., cellulis 15.6–21.6 × 8.4–14.4; appendicibus numerosis, 30–50 cr., hyalinis v. deorsum brunneis, perithecii diametrum paullo v. duplo superantibus,

continuis v. raro 1-septatis, flexuosis, irregulariter bifurcatis, ramulis ultimis inaequalibus, erectis; ascis 6–9 in quoque perithecio, ellipsoideis v. ovatis, brevissime pedicellatis, 50.4–68.4 × 30.0–46.8, 4–7-sporis; sporidiis longo-ellipsoideis, 16.8–21.6 × 9.6–19.2; conidiis maturis solitariis, longo-ellipsoideis v. cylindraceis, granulatis, 34.2–46.8 × 14.4–18.

Hab. On leaves of *Vicia unijuga* AL. BR. (Nanten-hagi)

Hokkaido—Prov. Ishikari: Sapporo (Oct. 8, 1890, E. TOKUBUCHI; Oct. 5, 1895, N. HIRATSUKA; Oct. 25, 1896, Oid. G. YAMADA); Maruyama (Oct. 15, 1903, T. MIYAGI; Oct. 25, 1930, Y. HOMMA); Makomanai (Oct. 5, 1904, T. MIYAGI).

Honshu—Prov. Musashi: Konodai (Oct. 15, 1904, T. MIYAGI); Komaba (Oct. 26, 1927, S. KUSANO). Prov. Bizen: Okayama (Dec. 2, 1929, S. IGATA, type). Prov. Inaba: Nakanogo-mura (Oct. 18, 1930, Y. TOCHINAI).

On *Vicia Tanakae* FR. & SAV. (Ohba-kusafuji)

Shikoku—Prov. Tosa: Kajiki, Konotani-mura (Sept. 1909, T. YOSHINAGA).

Distrib. Japan (Hokkaido, Honshu, Shikoku and Formosa) and China.

Remarks. The form on *Vicia unijuga* was included in *Erysiphe Polygoni* by SALMON. In Dec. 1929, an excellent specimen was kindly sent to us by Mr. IGATA from Okayama. In the young stage of this specimen, the appendages are hyaline, flexuous, almost simple and interwoven in the mycelial hyphae; in this case, it resembles *Erysiphe Pisi*. When matured, the appendages become light brown in color under middle portion, and branches are gradually developed. The branches are irregularly bifurcate, the apex of the ultimate branches being straight. From the above characters, the writer believes that the present fungus should better be transferred to Microsphaera rather than to be included in Erysiphe. It is related to *Microsphaera Bäumleri* on Vicia, from which it is distinguished by the appendages being exceedingly numerous and shorter in length and with the primary branches dividing near the base.

Microsphaera Russellii CLINT.

(Pl. X, fig. 23)

in PECK, Reg. Rep. XXVI, p. 80, 1874; SACC. Syll. Fung. I, p. 12, 1882; BURR. & EARLE, Bull. *Ill.* Stat. Lab. Nat. *Hist. II*, p. *415*, *1887*; ELL. & EVERH. N. Amer. Pyren. p. 23, 1892; SALM. Monogr. Erysiph. p. 163, 1900. (TRACY & GALLOW. Journ. Myc. IV, p. 35, *1888*; PAMM. Journ. Myc. IV, p. 38, 1888; SAWADA, Agr. Exp. Stat. Formosa, Bull.

IX, p. 58, 1914, and XIX, p. 174, 1919; Ideta, Jap. Phytopath. (Suppl. I) p. 213, 1923; SHIRAI & HARA, List, p. 217, 1927).

Syn. *Oidium Oxalidis* McAlp. Roy. Soc. Victoria, p. 219, 1894; SACC. Syll. Fung. XIV, p. 1041, 1899; LIND, Danish Fung. p. 165, 1913.

Amphigenous, also on shoots, mycelium persistent, at first forming white patches, and finally covering over the surface of the leaves; matured conidia solitary, ellipsoidal, elongate-ellipsoidal or cylindrical, granulate, vacuolate, 31.2–40.8 × 14.4–19.2 μ.

"Perithecia scattered, 70–118 μ in diameter, globose-depressed, cells small, 6–14 μ wide; appendages 5–14, 3–7 times the diameter of the perithecium, flaccid, septate, smooth, colored nearly to the apex when mature, apex 2–4 times dichotomously branched, branching very irregular and lax, primary branches usually long and forking widely, tips of ultimate branches not recurved; asci 4–9, narrowly to broadly ovate or (in small perithecia) ovate-globose, shortly stalked, 42–56 × 24–32 μ; spores 3–5, usually 4, 18–22 × 10–12 μ". (Salmon, Monogr. Erysiph. p. 163).

Hab. On leaves of *Oxalis corniculata* L. (Katabami). Hokkaido—Oshima, Ishikari. Honshu—Kozuke, Echigo, Etchu. Kyushu—Higo, Satsuma, Hiuga.

Distrib. Japan (Hokkaido, Honshu, Kyushu and Formosa) and North America.

Remarks. This species is found widely as a parasite on the wild Oxalis. The host plants wither much earlier in autumn than the healthy ones. The perithecial stage has not yet been collected in this country.

Oidium belonging to Microsphaera

On *Mahonia Fortunei* FEDDE (Hosoba-no-hiiraginanten). Honshu—Etchu.

Subfam. Phyllactinieae PALLA

Mycelial hyphae have internal and external forms. Special branches from the superficial mycelium passing through the stomata enter into the intercellular spaces of the mesophyll. When such internal hyphae have reached a certain length, they send haustoria into the surrounding spongy parenchyma or rarely into the palisade cells.

Key to the genera of the subfam. Phyllactinieae

1. Appendages acicular, conidiophores straight............... *Phyllactinia* (403)
2. Apex of the appendages uncinate, conidiophores form spirals at the base.. *Uncinulopsis* (418)

Phyllactinia LÉV.

Mycelial hyphae have two forms, external and interior, sending special branches from the external mycelium through the stomata into the intercellular spaces of the mesophyll and producing haustoria in the surrounding parenchyma cells. The matured conidia are clavate, solitary, arising on the long conidiophore. Perithecia are large, depressed-globose to lenticular, standing up with the reflexed appendages on the host surface and turning over when matured. The upper part of the perithecium is crowned with colorless shining cells, some of which grow into the so-called penicillata-cells. Appendages of the perithecium are acicular in form and bulbous at the base. Asci are many and spores number two or three.

In 1900, SALMON treated the numerous species of the genus which had been published up to that time as one species under the specific name, *Phyllactinia corylea* (PERS.) KARST. As the result of careful observations on the numerous specimens which have been collected at different parts of this country and of comparison with the American and European specimens, the writer has come to the conclusion that SALMON's *Phyllactinia corylea* must be divided into two sections of *Corylea* and *Fraxinii*. The former almost always has evanescent mycelia while the latter almost always has persistent ones.

The genus includes 9 species in this country.

Key to the species of the genus Phyllactinia

I. Corylea section.
Outer mycelium usually evanescent.
1. Perithecia 120—210 μ in diameter, asci 8—18 in number and spores 2—3 .... *P. corylea* (404)
2. Perithecia 183—238 μ in diameter, asci 9—14 in number, and spores always 2 .... *P. moricola* (407)

II. Fraxinii section.
Outer mycelium usually persistent.
1. Perithecia 175—273 μ in diameter, asci 12—30 in number .... *P. Fraxinii* (409)
2. Perithecia 182—266 μ in diameter, asci 6—13 in number .... *P. kakicola* (411)
3. Perithecia 224—273 μ in diameter, asci 15—21 in number and spores always 2 .... *P. Pyri* (412)
4. Perithecia 200—280 μ in diameter, asci about 9 in number .... *P. Actinidiae-formosanae* (414)
5. Perithecia 266—322 μ in diameter, asci 38 in number .... *P. quercus* (414)
6. Perithecia 294—364 μ in diameter, asci 15—20 in number .... *P. imperialis* (416)
7. Perithecia 345—415 μ in diameter, asci 20—24 in number .... *P. Actinidiae-latifoliae* (417)

Phyllactinia corylea (PERS.) KARST.

(Pl. XI, figs. 5-9)

Act. Soc. Faum. Fl. Fenn. II, p. 92, 1885; SALM. Monogr. Erysiph. p. 224 (p.p.), 1900, and Bull. Torr. Bot. Club, XXIX, p. 200 (p.p.), 1902; NEGER, Krypt. d. Mark Brand. VII, p. 134 (p.p.), 1905; KLIKA, Erysiph. Czechosl. p. 69 (p.p.), 1924; ŠKORIĆ, Erysiph. Croat. p. 55 (p.p.), 1926. (TAI & WEI, Sinensia III, p. 124 (p.p.), 1932; SALM. Bull. Torr. Bot. Club, XXVII, p. 445 (p.p.), 1900, Ann. Myc. III, p. 251 (p.p.), 1905, and VI, p. 10 (p.p.), 1908; MATSUM. Ind. Plant. Jap. I, p. 160, 1904; SHIRAI, List, p. 68 (p.p.), 1905; YOSHINO, Bot. Mag. Tokyo, XVIII, p. 3, 1906; IDETA, Jap. Phytopath. p. 215 (p.p.), 1911, and Jap. Phytopath. (Suppl. I), p. 217 (p.p.), 1923; SHIRAI & MIYAKE, List, p. 443 (p.p.), 1917; Hara, Dendropath. p. 28 (p.p.), 1923; SHIRAI & HARA, List, p. 266 (p.p.), 1927).

Syn. *Sclerotium Erysiphe* b. *corylea* PERS. Syn. Fung. p. 124, 1801.

Sclerotium suffulta REBENT. Prod. Fl. Neomarch. p. 360, 1804.

Erysiphe coryli HEDW. f. ex DC. Fl. Fr. II, p. 272, 1805.

Erysiphe guttata LK. in WILLD. Sp. Pl. VI, p. 116 (p.p.), 1824; MÉRAT, Nouv. Fl. Paris, p. 74 (p.p.), 1837, and Syn. Nouv. Fl. Paris, p. 83 (p.p.), 1837; RABENH. Deutschl. Krypt. Fl. I, p. 234 (p.p.), 1844; DE BARY, Beitr. Morphol. Phys. Pilz. I, xiii, p. 52 (p.p.), 1870.

Erysiphe guttata FR. Syst. Myc. III, p. 245 (p.p.), 1829; Tulasne, Selecta Fung. Carpolog. I, p. 194 (p.p.), 1861.

Phyllactinia guttata LÉV. Ann. Sci. Nat. III, 15, p. 144 (p.p.), 1851; KICKX, Crypt. Fl. Fland. I, p. 384, 1867; COOKE, Handb. Brit. Fung. II, p. 646 (p.p.), 1871; COOKE & PECK, Journ. Bot. I, p. 11, 1872; LIND, Danish Fung. p. 164 (p.p.), 1913. (FUCK. Symb. Myc. p. 79 (p.p.), 1869–70).

Phyllactinia Candollei LÉV. Ann. Sci. Nat. III, 15, p. 150, 1851; SACC. Syll. Fung. I, p. 5, 1885.

Phyllactinia guttata WALLR. in QUÉL. Champ. Jur. Vosg. p. 535 (p.p.), 1875.

Phyllactinia suffulta SACC. Mick. II, p. 50 (p.p.), 1880; SACC. Syll. Fung. I, p. 5 (p.p.), 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 42 (p.p.), 1884; BURR. & EARLE, Bull. Ill. Stat. Lab. Nat. Hist. II, p. 411 (p.p.), 1887; ELL. & EVERH. N. Amer. Pyren. p. 20 (p.p.), 1892; SCHRÖT. in COHN's Krypt. Fl. Schles. III, p. 246 (p.p.), 1893; JACZEW. Bull. l'Herb. Boiss. IV, p. 736 (p.p.), 1896; OUDEM. Rév. Champ. Pays-Bas, II, p. 85 (p.p.), 1897; JØRST. Erysiph. Norway, p. 103 (p.p.), 1925.

Phyllactinia suffulta REBENT. in PRILL. Malad. Pl. Agr. II, p. 29 (p.p.), 1897.

Phyllactinia corylea KARST. var. *rigida* SALM. Ann. Myc. III, p. 500 (p.p.), 1905.

Phyllactinia Sapii SAWADA, Depart. Agr. Govern. Research Inst. Formosa, Japan, Rep. XLIX, p. 53 and 81, 1930, and LXI, p. 37, 1933.

Ovulariopsis monospora SACC. & D. SACC. Syll. Fung. XVIII, p. 507, 1906; LIND. in RABENH. Krypt. Fl. Deutschl. IX, p. 727, 1910.

Amphigenous, mostly hypophyllous, mycelium evanescent; matured conidia solitary, clavate or broadly clavate, about 75.6 × 19.2 μ, granulate, vacuolate; perithecia gregarious or scattered, depressed-globose to lenticular, 120–210 μ in diameter; cells 12.0–16.8 × 10.8–13.2 μ in size; appendages 6–11 in number, usually 8, straight, needle-shaped, sharply pointed at the apex and bulbous at the base, 196–420 μ in length, hyaline, aseptate; penicillate cells formed at the apical portion of the perithecium, stalk-cells 24.0–26.4 × 8.4–9.6 μ

in size, branches about 11–20 in number, 24.0–25.2 μ in length; asci 8–18 in number, variable in forms, elongate-ellipsoidal or elongate-ovate, stalked, 62.4–92.4 × 30.0–45.6 μ; spores 2 or 3, oblong or ovate, 28.8–40.8 × 16.8–25.4 μ.

Hab. On leaves and young branchlets of *Corylus mandshurica* MAXIM. (Ohba-tsunohashibami). Hokkaido—Ishikari.

On *Corylus Sieboldiana* BL. (Tsuno-hashibami). Hokkaido—Ishikari.

On *Ostrya japonica* SARG. (Asada). Hokkaido—Ishikari.

On *Hamamelis japonica* SIEB. & ZUCC. (Mansaku). Honshu—Rikuchu.

On *Amelanchier asiatica* ENDL. (Zaifuriboku). Honshu—Inaba, Aki.

On *Cydonia sinensis* THOUIN. (Kwarin). Kyushu—Higo.

On *Caesalpinia japonica* SIEB. & ZUCC. (Jaketsu-ibara). Honshu—Hitachi. Shikoku—Tosa.

On *Picrasma quassioides* BENN. (Nigaki). Hokkaido—Ishikari. Honshu—Rikuchu.

On *Sapium sebiferum* ROXB. (Nankin-haze). Formosa—Shinchiku.

On *Rhododendron Albrechtii* MAXIM. (Murasaki-yashio-tsutsuji). Hokkaido—Ishikari.

Distrib. Japan (Hokkaido, Honshu, Shikoku, Kyushu and Formosa), China, Europe and North America.

Remarks. The specific name of *Phyllactinia corylea* used in this paper is of a strict sense and not similar to that advocated by SALMON. In this species, the development of the outer mycelia is scanty and finally evanescent, the diameter of the perithecia is smaller than that of the other related species, and asci, asco-spores and conidia are also smaller in size.

In 1900, SALMON published on the conidial stages of Phyllactinia, and he noted in his paper that conidia "varying in shape from clavate, clavate-oblong or clavate-obovate to clavate-elongate or clavate-spatulate or rarely clavate-fusiform or lemon-shaped, and rounded, acute, bluntly apiculate or rarely subacuminate at the apex, and varying in size from 45–85 × 15–25 μ" are found among them. He recorded three varieties of Phyllactinia based on the characters of the conidia,—*Phyll. corylea* var. *angulata*, var. *rigida*, and var. *subspiralis*. The first variety includes the form on Quercus, Ulmus and Fagus, and its conidia are angulate in form. On the second variety parasitic on *Parmentiera alata*, he noted: "the conidiophore is thick-walled, rigid and setiform, up to 500 μ long and about 5 μ wide". The third type is the form on *Dalbergia sissoo*, and the conidiophore

has the true spiral in the lower part. In the above three forms, a part of var. *rigida* forms the conidial stage of *Phyll. corylea.*

In the form on *Amelanchier japonica*, the asci and ascospores are largest in this species. Asci are 74.4–92.4 ×33.6–45.6 μ, and spores are 34.8–40.8 × 19.2–26.4 μ.

In 1930, *Phyllactinia Sapii* SAWADA on *Sapium sebiferum* ROXB. (coll. in Formosa, Shinchiku, Dec. 15, 1923, K. SAWADA) was published by SAWADA. The author was able to examine the co-type specimen by his kindness. In size the perithecia, asci, ascospores and conidia are similar to those of *Phyllactinia corylea*, but SAWADA treated it as a distinct species on the ground that the conidia did not infect the several other host plants. This species may better be recognized as a physiologic form.

Phyllactinia moricola (P. HENN.) HOMMA

(Pl. XI, fig. 10)

Trans. Sapporo Nat. Hist. Soc. XI, p. 174, 1930.

Syn. *Phyllactinia suffulta* (REB.) SACC. var. *moricola* P. HENN. in ENGL. Bot. Jahrb. XXVIII, p. 271, 1901; SACC. Syll. Fung. XVI, p. 399, 1902. (MATSUM. Ind. Plant. Jap. I, p. 160, 1904).

Phyllactinia corylea KARST. in SALM. Monogr. Erysiph. p. 224 (p.p.), 1900; TAI & WEI, Sinensia, III, p. 124 (p.p.), 1932. (SALM. Bull. Torr. Bot. Club, XXVII, p. 445 (p.p.), 1900, Ann. Myc. III, p. 251 (p.p.), 1905, and VI, p. 10 (p.p.), 1908; SHIRAI, List, p. 68 (p.p.), 1905; IDETA, Jap. Phytopath. p. 215 (p.p.), 1911, and Jap. Phytopath. (Suppl. I), p. 217 (p.p.), 1923; SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 72 (p.p.), 1914, and XIX, p. 189 (p.p.), 1919; SHIRAI & MIYAKE, List, p. 443 (p.p.), 1917; HARA, Dendropath. p. 28 (p.p.), 1923; SHIRAI & HARA, List, p. 266 (p.p.), 1927; MIURA, Fl. Manchuria and E. Mongolia, III, p. 140 (p.p.), 1927).

Phyllactinia suffulta P. HENN. in ENGL. Bot. Jahrb. XXXIV, p. 600, 1905.

Phyllactinia moricola (P. HENN.) SAWADA, Depart. Agr. Govern. Research Inst. Formosa, Japan, Rep., XLIX, p. 84, 1930, and LXI, p. 34, 1933.

Phyllactinia Broussonetiae-Kaempferi SAWADA, Depart. Agr. Govern. Research Inst. Formosa, Japan, Rep., XLIX, p. 87, 1930.

Ovulariopsis moricola G. DELACR. Bull. Soc. Myc. France, XIX, p. 345, 1903; SACC. Syll. Fung. XVIII, p. 506, 1906.

Amphigenous, mostly hypophyllous, mycelium generally evanescent, rarely more or less persistent; conidiophores long, matured conidia solitary, large, clavate or broadly clavate, not papillate or rarely papillate, granulate, 62.4–72.0 × 24.0–31.2 μ; perithecia scattered, depressed-globose to lenticular, 182–238 μ in diameter; cells 13.2–21.6 × 7.2–15.6 μ; appendages 7–13 in number, usually 8, straight, needle-shaped, sharply pointed at the apex, bulbous at the base, 210–378 μ in length, hyaline, aseptate; penicillate cells, stalk-cells 33.6–40.8 × 12.0–19.2 μ in size, branches 11–36 in number, and 21.6–36.0 μ in length; asci 5–16 in number, elongate-ovate or cylindrical, stalked, 75.0–88.8 × 31.2–45.6 μ; spores 2, ellipsoidal, 27.6–40.0 × 19.2–26.4 μ.

Hab. On leaves of *Broussonetia Kaempferi* SIEB. (Tsuru-kozo). Kyushu—Hizen.

On *Broussonetia Kazinoki* SIEB. (Kozo). Honshu—Musashi.

On *Morus bombycis* KOIDZ. (Yama-guwa). Hokkaido—Shiribeshi, Iburi, Ishikari, Kitami. Honshu—Mutsu, Rikuchu, Ugo, Iwaki, Musashi, Shimozuke, Etchu, Echizen, Kaga, Shinano, Mino, Inaba. Shikoku—Iyo, Tosa. Kyushu—Higo.

Distrib. Japan (Hokkaido, Honshu, Shikoku, Kyushu, Korea and Formosa), Manchuria, China, Philippines, Indo-China, Burma and Madagascar.

Remarks. The form on Morus was included in *Phyllactinia corylea*, or *Phyllactinia suffulta* or *Phyllactinia guttata* for a long time. In 1901, P. HENNINGS recorded it as a new variety of *Phyllactinia suffulta*. This variety was founded on the specimen collected by Prof. M. MIYOSHI on *Morus alba* in Tokyo in Oct. 1899. His description is "mycelio hypophyllo, effuso, crassiusculo cretaceo vel flavidulo, villosulo; peritheciis sparsis, globuloso-depressis ca. 180–220 μ atrobrunneis; appendicibus (8–13), hyalinis subulatis ca. 120–150 μ longis basi vesiculoso inflatis ca. 30 μ crassis; ascis (5–16) clavatis, basi stipitatis curvulis 2-sporis, ca. 60–65 × 30 μ; sporis ellipsoideis 30–40 × 16–28 μ aurantiaco-oleosis. Diese Varietät ist von der typischen Art schon äusserlich durch das dickfilzige, weisse bis gelbliche Mycel gut verschieden". Mycelium on most of the leaves of *Morus bombycis* is evanescent, but occasionally on the thickish leaves it is persistent forming a thick felt-like mycelial layer. In this species, the diameter of the perithecium is larger than that of typical *Phyllactinia corylea*. In both of these species, the infected portions of the host leaves are changed to a yellowish color.

Phyllactinia parasitic on *Broussonetia Kaempferi* collected in Prov. Hizen, was considered by SAWADA as a new species, under the

name of *Phyllactinia Broussonetiae-Kaempferi*. The present writer could not distinguish it by the characters of the perithecial stage from *Phyllactinia moricola*, although SAWADA affirmed that the form did not infect mulberry-leaves. It is better to consider it as a physiologic form.

Phyllactinia Fraxini (DC.) HOMMA, comb. nov.

(Pl. XI, figs. 11, 12)

Syn. *Erysiphe fraxini* DC. Fl. Fr. II, p. 273, 1805.

Erysiphe betulae DC. Fl. Fr. VI, p. 107, 1915.

Erysiphe guttata LK. in WILLD. Sp. Pl. VI, p. 116 (p.p.), 1924; MÉRAT, Nouv. Fl. Paris, p. 74 (p.p.), 1837, and Syn. Nouv. Fl. Paris, p. 83 (p.p.), 1837; RABENH. Deutschl. Krypt. Fl. I, p. 234 (p.p.), 1844; DE BARY, Beitr. Morphol. Phys. Pilz. I, xiii, p. 52 (p.p.), 1870.

Erysiphe guttata FR. Syst. Myc. III, p. 245 (p.p.), 1829; TULASNE, Selecta Fung. Carpolog. I, p. 194, 1861.

Erysiphe lenticularis RABENH. Deutschl. Krypt. Fl. I, p. 234, 1844.

Phyllactinia guttata LÉV. Ann. Sci. Nat. III, 15, p. 144 (p.p.), 1851; COOKE, Handb. Brit. Fung. II, p. 646 (p.p.), 1871; LIND, Danish Fung. p. 164 (p.p.), 1913. (FUCK. Symb. Myc. p. 79 (p.p.), 1869–70).

Phyllactinia guttata WALLR. in QUÉL. Champ. Jur. Vosg. p. 535 (p.p.), 1875.

Phyllactinia suffulta SACC. Mich. II, p. 50 (p.p.), 1880, SACC. Syll. Fung. I, p. 5 (p.p.), 1882; WINT. in RABENH. Krypt. Fl. Deutschl. I, 2, p. 42 (p.p.), 1884; BURR. & EARLE, Bull. Ill. Stat. Lab. Nat. Hist. II, p. 411 (p.p.), 1887; ELL. & EVERH. N. Amer. Pyren. p. 20 (p.p.), 1892; SCHRÖT. in COHN's Krypt. Fl. Schles. III, p. 246 (p.p.), 1893; JACZEW. Bull. l'Herb. Boiss. IV, p. 736 (p.p.), 1896; OUDEM. Rév. Champ. Pays-Bas, II, p. 85 (p.p.), 1897; MAGNUS, Erysiph. Tirol. p. 22 (p.p.), 1898; JØRST. Erysiph. Norway, p. 103 (p.p.), 1925.

Phyllactinia suffulta REBENT. in PRILL. Malad. Pl. Agr. II, p. 29 (p.p.), 1897.

Phyllactinia corylea KARST. in SALM. Monogr. Erysiph. p. 224 (p.p.), 1900, and Bull. Torr. Bot. Club, XXIX, p. 200 (p.p.), 1902; NEGER, Krypt. d. Mark Brand. VII, p. 134 (p.p.), 1905; KLIKA, Erysiph. Czechosl. p. 69 (p.p.), 1924; ŠKORIĆ, Erysiph. Croat. p. 55 (p.p.), 1926; TAI & WEI, Sinensia, III, p. 124 (p.p.), 1932. (SALM. Bull. Torr. Bot. Club, XXVII, p. 445 (p.p.), 1900, Ann. Myc. III,

p. 251 (p.p.), 1905, and VI, p. 10 (p.p.), 1908; SHIRAI, List, p. 68 (p.p.), 1905; SYD. Ann. Myc. VII, p. 170, 1909; IDETA, Jap. Phytopath. p. 215 (p.p.), 1911, and Jap. Phytopath. (Suppl. I), p. 217 (p.p.), 1923; SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 72 (p.p.), 1914, and XIX, p. 186 (p.p.), 1919; SHIRAI & MIYAKE, List, p. 443 (p.p.), 1917; HARA, Dendropath. p. 28 (p.p.), 1923; SHIRAI & HARA, List, p. 266 (p.p.), 1927).

Phyllactinia corylea KARST. var. *rigida* SALM. Ann. Myc. III, p. 500 (p.p.), 1905.

Hypophyllous, very rarely amphigenous, mycelium persistent, forming thick white patches; matured conidia solitary, clavate or broadly clavate, papillate or not, 52.8–91.2 × 18.0–27.6 μ, granulate, vacuolate, sometimes including well-developed fibrosin bodies; perithecia gregarious, large, depressed-globose to lenticular, 175–273 μ in diameter; cells 12.0–24.0 × 9.6–20.4 μ in size; appendages 8–21 in number, straight, bulbous at the base, aseptate or very rarely septate (form on *Fraxinus mandshurica* var. *japonica*), 210–476 μ in length; penicillate-cells, stalk-cells 28.8–45.6 × 9.6–13.2 μ in size, sometimes dichotomously branched at the apical portion, branches 14–20 in number, 14.4–40.8 μ in length; asci 12–30 in number, elongate-ellipsoidal or elongate-ovate, stalked, 63.6–100.6 × 26.4–45.6 μ; spores 2 or 3 in number, usually 2, very rarely 4, 27.6–45.6 × 16.8–31.2 μ in size.

Hab. On leaves and stems of *Juglans Sieboldiana* MAXIM. (Onigurumi). Hokkaido—Ishikari. Honshu—Rikuchu.

On *Alnus alnobetula* HARTIG var. *fruticosa* WINKL. (Miyama-hannoki). Hokkaido—Iburi.

On *Alnus hirsuta* TURCZ. (Keyama-hannoki). Hokkaido—Ishikari.

On *Alnus hirsuta* TURCZ. var. *sibirica* SCHNEID. (Yama-hannoki). Hokkaido—Iburi, Ishikari. Honshu—Musashi, Kozuke.

On *Alnus japonica* SIEB. & ZUCC. (Hannoki). Honshu—Rikuchu, Musashi, Echigo. Shikoku—Sanuki.

On *Alnus japonica* SIEB. & ZUCC. var. *arguta* CALL. (Yezo-hannoki). Hokkaido—Ishikari. Honshu—Musashi.

On *Alnus koreana* NAKAI (Hiroha-keyama-hannoki). Hokkaido—Ishikari.

On *Alnus obtusata* MAKINO (Kawara-hannoki). Shikoku—Tosa.

On *Betula Tauschii* KOIDZ. (Shirakamba). Hokkaido—Ishikari.

On *Magnolia praecocissima* KOIDZ. (Kobushi). Honshu—Rikuchu, Ugo, Musashi.

On *Magnolia praecocissima* KOIDZ. var. *borealis* KOIDZ. (Kitakobushi). Hokkaido—Ishikari.

On *Schizophragma hydrangeoides* SIEB. & ZUCC. (Iwagarami). Hokkaido—Ishikari.

On *Actinidia arguta* PLANCH. (Kokuwa). Hokkaido—Ishikari, Kushiro.

On *Actinidia polygama* MAXIM. (Matatabi). Hokkaido—Ishikari.

On *Fraxinus mandschurica* RUPR. (Yachidamo). Saghalien—Ochiai. Hokkaido—Ishikari, Kushiro. Honshu—Ugo.

On *Fraxinus pubinervis* BLUME (Toneriko). Honshu—Echigo.

On *Fraxinus Sieboldiana* BLUME (Aodamo). Honshu—Echigo.

Distrib. Japan (Saghalien, Hokkaido, Honshu, Shikoku, Kyushu and Formosa), Manchuria, China, Europe, Africa and North America.

Remarks. This species is the most common powdery mildew on deciduous trees, especially often attacking the young plants of the nursery. In 1928, the writer observed the Fraxinus seedlings in the experimental nursery of this University, very badly attacked by the mildew. At first, white patches appeared on the under surface of the leaves of these young trees, and gradually spread on the upper surface, and at last numerous perithecia were produced on the mycelial masses. Some of the seedlings succumbed entirely.

The special characters of this species are the presence of the evident white mycelial patches on the under surface of the leaves, and of the perithecia produced on these dense white masses which can easily be recognized with the naked eye. This species is distinguished from *Phyllactinia corylea* and *Phyllactinia moricola* by the size of the perithecia and the persistent mycelium. In *Phyllactinia quercus* the diameter of the perithecia is larger than in the case of the present species.

In the present species, there are two or three spores in an ascus, but usually two. The spores in the two-spored asci are larger, 33.6–40.8 × 25.2–28.8 μ, while those in the three-spored ones are smaller, 27.6–28.8 × 16.8–17.6 μ.

In the form on *Fraxinus mandschurica*, the appendages sometimes have a slight swelling at the upper part of the bulbous base, and are sometimes 1 to 3 septate. (coll. in Sapporo, Oct. 19, 1923).

In the form on *Magnolia praecocissima* var. *borealis*, the asci and ascospores are yellowish in color caused by the numerous yellowish drops inclosed in the cell.

Phyllactinia kakicola SAWADA

Depart. Agr. Govern. Research Inst. Formosa, Japan, Rep. XLIX, p. 51, and 80, 1930, and LXI, p. 33, 1933.

Syn. *Phyllactinia corylea* (PERS.) KARST. in SALM. Ann. Myc. III, p. 251 (p.p.), 1905, and VI, p. 10 (p.p.), 1908; TAI & WEI,

Sinensia, III, p. 124 (p.p.), 1932. (SHIRAI & MIYAKE, List, p. 443 (p.p.), 1917; IDETA, Jap. Phytopath. (Suppl. I), p. 217 (p.p.), 1923; HARA, Dendropath. p. 28 (p.p.), 1923; SHIRAI & HARA, List, p. 266 (p.p.), 1927).

Hypophyllous, mycelium persistent or rarely evanescent; "conidia clavate, papillate, 60–116 × 27–44 μ in size" (acc. to Sawada, p. 51); perithecia gregarious, depressed-globose to lenticular, 182–226 μ in diameter; cells 14.4–21.6 × 14.4–20.4 μ in size; appendages 8–13 in number, hyaline, aseptate, 250–301 μ in length; penicillate cells, stalk-cells 40.8–50.4 × 13.2–16.8 μ in size, branches about 16–25 in number, 21.6–24.0 μ in length; asci 6–13 in number, ellipsoidal or elongate-ellipsoidal, 60.0–84.0 × 26.4–36.0 μ in size; spores always 2, oblong or ellipsoidal, 33.6–36.0 × 18.0–19.2 μ in size.

Hab. On leaves of *Diospyros Kaki* L. f. (Kaki). Honshu—Musashi, Echigo, Etchu, Echizen, Mino, Bizen, Inaba. Kyushu—Buzen, Higo.

On *Diospyros Lotus* L. (Mame-gaki). Honshu—Rikuchu.

Distrib. Japan (Honshu, Kyushu and Formosa) and China.

Remarks. The species parasitic on *Diospyros Kaki* was first recorded by SALMON in 1905 as *Phyllactinia corylea*, which was collected in Tokyo in 1904 by S. KUSANO.

In 1930, this fungus was separated from *Phyllactinia Corylea* by SAWADA and was named *Phyllactinia kakicola*. The conidia and ascospores of the latter are larger than those of the former and the conidia did not infect *Morus*, *Broussonetia papyrifera*, *Pirus serotina*, *Sapium sebiferum*, *Ampelopsis heterophylla*, and *Cephalanthus occidentalis*.

Phyllactinia Pyri (CAST.) HOMMA, comb. nov.

Syn. *Erysiphe Pyri* CAST. Cat. Pl. Mars. p. 190, 1845.

Phyllactinia guttata b. *Pyri* FUCK. Symb. Myc. p. 79, 1869–70.

Phyllactinia suffulta SACC. Syll. Fung. I, p. 5 (p.p.), 1882.

Phyllactinia suffulta SACC. f. *Pyri* REHM. Ascomyc. ex. No. 797, 1885.

Phyllactinia corylea KARST. in SALM. Monogr. Erysiph. p. 224 (p.p.), 1900, Bull. Torr. Bot. Club, XXIX, p. 200 (p.p.), 1902, and Ann. Myc. VI, p. 10 (p.p.), 1908; ŠKORIĆ, Erysiph. Croat. p. 55 (p.p.), 1926; TAI & WEI, Sinensia, III, p. 124 (p.p.), 1932. (SAWADA, Agr. Exp. Stat. Formosa, Bull. XIX, p. 189 (p.p.), 1919; IDETA, Jap.

Phytopath. (Suppl. I), p. 217 (p.p.), 1923; HARA, Dendropath. p. 28 (p.p.), 1923; SHIRAI & HARA, List, p. 266 (p.p.), 1927; MIURA, Fl. Manchuria and E. Mongolia, III, p. 140 (p.p.), 1932).

Phyllactinia Pyri-serotinae SAWADA, Depart. Agr. Govern. Research Inst. Formosa, Japan, Rep. XLIX, p. 59 and 83, 1930, and LXI, p. 36, 1933.

Hypophyllous, mycelium persistent or rarely evanescent; "conidia solitary, clavate, not papillate, 63–104 × 20–32 μ in size" (Acc. to Sawada, p. 60); perithecia gregarious or sometimes scattered, depressed-globose to lenticular, 224–273 μ in diameter; cells 15.6–16.8 × 13.2–14.4 μ in size; appendages 8–12 in number, aseptate, hyaline, 316–376 μ in length; penicillate cells, stalk-cells 19.2–33.6 × 12.0–14.4 μ in size, branches wide, 5 or 6 in number, 26.4–36.0 μ in length; asci 15–25 in number, ellipsoidal, stalked, reaching 24 μ in length, 69.6–86.4 × 31.2–38.8 μ in size; spores 2, oblong or ellipsoidal, 33.6–38.4 × 16.8–21.6 μ in size.

Hab. On leaves of *Pirus communis* L. (Seiyo-nashi). Honshu—Echigo.

On *Pirus sinensis* LINDL. var. *culta* MAKINO (Nashi). Honshu—Rikuchu, Musashi, Echigo, Bitchu, Inaba. Shikoku—Iyo. Kyushu—Hizen.

Distrib. *Japan (Honshu, Shikoku, Kyushu and Formosa), China and* Europe.

Remarks. SAWADA proved that this species does not infect *Morus multicaulis*, but does infect *Pirus Lindleyi*, and that the conidia of Phyllactinia on *Alnus formosana, Diospyros Kaki, Sapium sebiferum* and *Broussonetia papyrifera* do not infect *Pirus serotina*. Besides, the conidia of the present species have a constriction at the middle portion, and their internal mycelium is composed of three cells, and produces a tubercular process near the apex. Compared with "*Erysiphe Pyri* CAST." on *Pirus communis* it is always 2-spored in an ascus. From the above mentioned characters, the present fungus was regarded as a new species by SAWADA.

The writer has studied the form on *Pirus communis* which was collected in this country, and found it to be similar to the form on *Pirus sinensis*. Then, it seemed that the present species should be compared with the original specimen of Phyllactinia on the European *Pirus communis*. Very kindly, a part of the specimens of *Phyllactinia suffulta* (REBENT.) SACC. f. *Pyri* REHM on Pyrus of "REHM's Ascomyceten, No. 797" was given to the writer by Sir ARTHUR HILL, the Director of the Royal Botanic Gardens, Kew, upon request. The

result of the careful examination of this specimen is as follows:

Hypophyllous, mycelium persistent; perithecia 182–224 μ; cells 16.8–24.0 × 12.0–16.8 μ in size; appendages 8–10 in number, 280 μ in length; asci 13–20 in number, 68.4–76.8 × 33.6–37.2 μ in size; spores two, 31.2–36.0 × 16.0–16.8 μ in size. In this form, 2 spores were included in an ascus, although the spores had been recorded as 2–4 in number in the original description of H. REHM. The form of our collections and the European form are similar in characters in all essential points.

Phyllactinia Actinidiae-formosanae SAWADA

Depart. Agr. Govern. Research Inst. Formosa, Japan, Rep. XLIX, p. 56 and 82, 1930, and LXI, p. 29, 1933.

Hypophyllous, mycelium evanescent; "conidia solitary, clavate or elongate-obovate, 52–104 × 23–36 μ in size, vacuolate, granulate, rounded at the apex" (acc. to Sawada, p. 56); perithecia gregarious or scattered, depressed-globose to lenticular, 200–280 μ in diameter; cells obscure; appendages 9–15 in number, 287–564 μ in length, hyaline, blunt at the apex; asci about 9, stalked, ellipsoidal or ovate, 52.8–57.6 × 24.0–26.4 μ; spores immatured.

Hab. On leaves of *Actinidia formosana* Hay. (Taiwan-sarunashi). Formosa—Daihoku.

Distrib. Japan (Formosa).

Remarks. The present species is related to *Phyllactinia Fraxinii* on *Actinidia arguta*. In the form on *Actinidia arguta*, the conidia have a distinct papilla at the apex, the asci are more numerous and larger, besides, the appendages are acute at the apex.

Phyllactinia quercus (MÉR.) HOMMA, comb. nov.

(Pl. XI, fig. 13)

Syn. *Erysiphe quercus* MÉRAT, Rév. Fl. Par. p. 459, 1843.

Phyllactinia guttata LÉV. Ann. Sci. Nat. III, 15, p. 144 (p.p.), 1851; COOKE, Handb. Brit. Fung. II, p. 646 (p.p.), 1871. (FUCK. Symb. Myc. p. 80 (p.p.), 1869–70).

Phyllactinia suffulta SACC. Mich. II, p. 50 (p.p.), 1880; SACC. Syll. Fung. I, p. 5 (p.p.), 1882; WINT. in RABENH. Krypt. Fl.

Deutschl. I, 2, p. 42 (p.p.), 1884; BURR. & EARLE, Bull. Ill. Stat. Lab. Nat. Hist. II, p. 441 (p.p.), 1887; ELL. & EVERH. N. Amer. Pyren. p. 20 (p.p.), 1892; SCHRÖT. in COHN's Krypt. Fl. Schles. III, p. 246 (p.p.), 1893; JACZEW. Bull. l'Herb. Boiss. IV, p. 736 (p.p.), 1896; MAGNUS, Erysiph. Tirol. p. 22 (p.p.), 1898.

Phyllactinia corylea KARST. in SALM. Monogr. Erysiph. p. 224 (p.p.), 1900, and Bull. Torr. Bot. Club, XXIX, p. 200 (p.p.), 1902; NEGER, Krypt. d. Mark. Brand. VII, p. 134 (p.p.), 1905; TAI & WEI, Sinensia, III, p. 124 (p.p.), 1932. (SALM. Bull. Torr. Bot. Club, XXVII, p. 445 (p.p.), 1900, Ann. Myc. III, p. 251 (p.p.), 1905; SHIRAI, List, p. 68 (p.p.), 1905; Ideta, Jap. Phytopath. p. 251 (p.p.), 1911; SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 72 (p.p.), 1914; SHIRAI & MIYAKE, List. p. 443 (p.p.), 1917; SHIRAI & HARA, List, p. 266 (p.p.), 1927).

Hypophyllous, mycelium subpersistent; perithecia scattered, depressed-globose to lenticular, 266–322 μ in diameter; cells 13.2–13.6 $\times$ 9.6–10.6 μ in size; appendages 16–21 in number, hyaline, straight, bulbous at the base, aseptate, needle-shaped, 252–329 μ in length; asci numerous, about 38 in number, stalked, reaching 21.6 μ in length, elongate-ellipsoidal, 69.6–93.6 $\times$ 28.8–38.4 μ; spores usually 2, rarely 3, ellipsoidal, frequently including well-developed fibrosin bodies, 30.0–44.4 $\times$ 20.4–25.2 μ in size.

Hab. On leaves of *Castanea crenata* SIEB. & ZUCC. (Kuri). Honshu—Hitachi, Izu. Kyushu—Higo.

On *Quercus serrata* THUNB. (Konara). Kyushu—Higo.

On *Quercus variabilis* BLUME (Abemaki). Kyushu—Higo.

Distrib. Japan (Honshu and Kyushu), China, Europe and North America.

Remarks. In *Quercus serrata* and *Castanea crenata*, many species of Erysiphaceae are frequently found parasitic on the same leaf, but the present species can easily be distinguished from others by its larger parithecia. In this species, the size of the perithecia is greater than that of *Phyllactinia Fraxini* and the mycelial patches are more or less thinner. Compared with *Phyllactinia imperialis*, the diameter of the perithecium is smaller in the species under consideration and the asci are 38 to a perithecium, while in *Phyllactinia imperialis*, they are 15–20.

Phyllactinia imperialis MIYABE, in sched.
Herb. Hokkaido Imp. Univ.

(Pl. XI, fig. 14)

Syn. *Phyllactinia corylea* KARST. in SALM. Ann. Myc. IV, p. 10 (p.p.), 1908. (SHIRAI & MIYAKE, List, p. 443 (p.p.), 1917; IDETA, Jap. Phytopath. (Suppl. I), p. 217 (p.p.), 1923; SHIRAI & HARA, List, p. 266 (p.p.), 1927; HARA, Dendropath. p. 28 (p.p.), 1932).

Amphigenous, mostly hypophyllous, mycelium persistent, at first forming white patches on the leaves and finally effused over the lower surface, and turning to a brownish color; matured conidia solitary, very large, vacuolate, granulate, broadly clavate or lemon-shaped, not papillate, 60.0–76.8 × 24.0–40.8 μ; perithecia gregarious or scattered, depressed-globose to lenticular, 294–364 μ in diameter; cells 20.9–28.5 × 19.0–28.8 μ in size; appendages 19–25 in number, straight, simple, with sharp apex and bulbous base, 154–476 μ in length, aseptate; penicillate cells, stalk-cells 50.4–72.0 × 12.0–26.4 μ in size, frequently bifurcate at the upper part, branches about 14–20 in number, 33.6 μ in length; asci 15–20 in number, elongate-ovate, stalked, 79.2–98.2 × 34.8–45.6 μ; spores always 2, oblong or ovate, 33.6–40.8 × 19.2–26.4 μ.

Hab. On leaves of *Paulownia tomentosa* STEUD. (Kiri). Hokkaido—Shiribeshi, Ishikari. Honshu—Mutsu, Rikuchu, Rikuzen, Ugo, Musashi, Echigo, Etchu, Echizen, Kaga, Yamashiro, Inaba. Shikoku—Iyo. Kyushu—Higo.

Distrib. Japan (Hokkaido, Honshu, Shikoku and Kyushu).

Remarks. The form on *Paulownia tomentosa* was named *Phyllactinia imperialis* by Prof. MIYABE in 1900. In this fungus, the perithecia and conidia are remarkably large in size.

In 1900, SALMON noted, "Professor MIYABE has sent me specimens of a very beautiful form on *P. corylea* from Japan, growing on *Paulownia imperialis*. The form is remarkable for its large size. Many of the perithecia reach a diameter of 350 μ; the appendages are more numerous than usual, being sometimes as many as 25, when they are arranged so closely round the perithecium that their bulbous bases touch one another. In these perithecia the asci and spores show, likewise, a tendency to be larger than usual. Intermixed with these large perithecia, however, are others which, in the smaller size of all their parts, agree perfectly in every respect with ordinary *Phyl. corylea*. Altogether, we cannot consider that the *Phyllactinia* on *Paulownia*

is anything but a luxuriant form of *P. corylea*, which it would be inadvisable to separate even as a variety. It is most probable that further search on other Japanese plants would bring to light a complete series of forms of *Phyllactinia* intermediate in size between this large form on *Paulownia* and those of normal size". The writer has made very careful comparative studies on this species using many specimens from every part of this country. As the result of the observation, it clearly should be recognized as a distinct species from the following characters: the conidia are much larger and broadly clavate or lemon-shaped, with rounded apex, the diameter of the perithecia is remarkably large, reaching 364 μ and appendages are 19–25 in number.

The leaves of *Paulownia tomentosa* fall early in autumn when affected, thereby greatly injuring the growth of the tree.

Phyllactinia Actinidiae-latifoliae SAWADA

Depart. Agr. Govern. Research Inst. Formosa, Japan, Rep. XLIX, p. 57 and 82, 1930, and LXI, p. 30, 1933.

Hypophyllous, mycelium persistent, at first forming white patches and finally becoming a light brown color; "conidia solitary, fusiform-ellipsoidal or spindle-shaped, not papillate, granulate, vacuolate, 50–102 × 22–35 μ in size". (acc. to Sawada, p. 58) ; perithecia scattered, depressed-globose to lenticular, 350–434 μ in diameter; cells 14.4–16.8 × 10.8–12.0 μ in size; appendages 18–24 in number, straight, blunt at the apex, 280–574 μ in length; penicillate-cells, stalk-cells 16.8–21.6 × 4.8–7.2 μ in size, branches 8–11 in number, 19.2–24.0 μ in length; asci 20–24 in number, elongate-ellipsoidal or cylindrical, stalked, 64.8–84.6 × 21.6–28.8 μ; spores immatured.

Hab. On leaves of *Actinidia latifolia* NAKAI (Birodo-sarunashi). Formosa—Daihoku.

Distrib. Japan (Formosa).

Remarks. Mr. SAWADA kindly gave the writer a very beautiful co-type specimen. This made it possible to make a careful comparative study with the other species on Actinidia. The perithecia and conidia of the present species are much larger and the appendages are more numerous than those of the other species. Compared with

Phyllactinia imperialis which has a large perithecium, that of the present form is even larger. According to the description of SAWADA, the asci are said to be immature, but the present writer found that the asci are already produced in many perithecia, although the ascospores are in an immature stage.

Ovulariopsis belonging to Phyllactinia

Ovulariopsis Alni-formosanae SAW.
On *Alnus formosana* (Burkill.) MAK. (Taiwan-hannoki)
Ovul. Asclepiadis-curassavicae SAW.
On *Asclepias curassavica* L. (Towata)
Ovul. Ampelopsidis-heterophyllae SAW.
On *Ampelopsis heterophylla* S. & Z. (No-budo)
Ovul. Ampelopsidis-ciliatae SAW.
On *Ampelopsis heterophylla* S. & Z. var. *ciliata* NAKAI (Ke-nobudo)
Ovul. Cephalanthi SAW.
On *Cephalanthus occidentalis* L. (Tamakasanoki)
Ovul. Caricae SAW.
On *Carica Papaya* L. (Papaya).
Ovul. Macarangae SAW.
On *Macaranga Tanarius* (L.) MUELL. Arg. (Ohbagi)
Ovul. Salicis-Warburgi SAW.
On *Salix glandulosa* SEEM. var. *Warburgi* (SEEM.) KOIDZ. (Taiwan-yanagi)
Ovul. Broussonetiae-papyriferae SAW.
On *Broussonetia papyrifera* VENT. (Kajinoki)

The above 9 species of Ovulariopsis were described by SAWADA in the Reports of the Department of Agriculture Government Research Institute Formosa, Japan, No. *49, 1930* and No. *61, 1933.*

Uncinulopsis SAWADA

Mycelial hyphae in two forms, external and internal, sending special branches from the external mycelium through stomata into intercellular spaces of the mesophyll and producing haustoria in the surrounding cells. Conidiophore formed from the external mycelium, is long, producing true spirals at the base. Matured conidia solitary, elongate-ellipsoidal or clavate. Perithecia large, lenticular in shape; appendages numerous, simple, uncinate at the apex; asci many and spores 2–4 in number.

The genus includes a single species, *Uncinulopsis Shiraiana,* in this country.

Uncinulopsis Shiraiana (P. HENN.) HARA
(*Pl. XI, fig. 4*)

Dendropath. p. 26, 1923; TAI & WEI, Sinensia, III, p. 122, 1932.

Syn. *Uncinula polychaeta* (not of B. & C.) SALM. Monogr. Erysiph. p. 113 (p.p.), 1900, and Bull. Torr. Bot. Club, XXIX, p. 101, 1902. (MATSUM. Ind. Plant. Jap. I, p. 178, 1904; SALM. Ann. Myc. III, p. 253, 1905, and VI, p. 12, 1908; SHIRAI, List, p. 103, 1905; YOSHINO, Bot. Mag. Tokyo XIX, p. 206, 1905; IDETA, Jap. Phytopath. p. 214, 1911; SHIRAI & MIYAKE, List, p. 677, 1917).

Uncinula Shiraiana P. HENN. in ENGL. Bot. Jahrb. XXIX, p. 148, 1901; SACC. Syll. Fung. XVI, p. 400, 1902. (SHIRAI, List, p. 103, 1905; SHIRAI & MIYAKE, List, p. 679, 1917).

Phyllactinia corylea KARST. var. *subspiralis* SALM. Ann. Myc. III, p. 501 (p.p.), 1905.

Phyllactinia subspiralis SAWADA, Agric. Exp. Stat. Formosa, Bull. IX, p. 75, 1914.

Uncinulopsis subspiralis SAWADA, Trans. Form. Nat. Hist. Soc. XXIII, p. 34, 1916, and Agric. Exp. Stat. Formosa, Bull. XIX, p. 182, 1919.

Hypophyllous, mycelium persistent, forming dense white masses; matured conidia solitary, elongate-ellipsoidal or clavate-ellipsoidal, not papillate, 45.6–57.6 × 14.4–18.0 μ in size; conidiophore long, thin-walled, forming sinistrorse spirals, 3 or 4 times at the base; perithecia scattered, large, lenticular in shape, 196–322 μ in diameter; cells 16.8–21.6 × 10.8–13.2 μ in size; appendages very numerous, hyaline, aseptate, variable in length, 112–210 μ, rarely 72 μ, simple, slender, flexuous, apex uncinate or helicoid; asci 20–40 in number, elongate-ovate or elongate-ellipsoidal, stalked, 72.8–92.0 × 24.0–36.0 μ; spores 3–4, usually 3, very rarely 2, subglobose, oblong or ovate, 19.2–30.0 × 13.2–21.6 μ.

Hab. On leaves of *Celtis sinensis* Pers. (Enoki). Honshu—Musashi, Hitachi, Etchu, Kaga, Suruga, Mino, Kai, Bitchu, Inaba, Hoki. Shikoku—Awa. Kyushu—Hizen, Higo, Satsuma. Formosa—Daihoku.

Distrib. Japan (Honshu, Shikoku, Kyushu and Formosa) and China.

Remarks. The first record of the presence of the present species in Japan was by SALMON in 1900, based on the specimen sent by Prof. MIYABE, accompanied with a note, "*Uncinula* n. sp. related to

U. polychaeta, but trisporous, on *Celtis sinensis* (as *Aphananthe aspera*), Tokyo, Japan, October 29, 1895 (K. SENGOKU)". It was noted by SALMON that in this Japanese specimen most of the asci are 3-spored, although there may be frequently found 2-spored ones, and the fungus is evidently to be referred to *U. polychaeta*.

In 1901, P. HENNINGS published a new species under the name of *Uncinula Shiraiana* parasitic on *Celtis sinensis* which was collected in Tokyo, Oct. 26, 1899, by S. KUSANO. He noted that this species is distinguished from the American *Uncinula polychaeta* by the more numerous asci, and by the presence of 3 or 4 yellowish colored spores.

In 1905, SALMON reported a new variety, *subspiralis* of *Phyllactinia corylea* on *Dalbergia Sissoo* as the result of studies on the conidial stage of *Phyllactinia corylea*, and remarked that the perithecial stage of this fungus was still unknown.

In 1914, SAWADA reported that the conidial stage on *Celtis sinensis* belongs to *Phyllactinia corylea* var. *subspiralis* SALM. and he elevated it to specific rank as *Phyllactinia subspiralis* (SALM.) SAWADA.

In the form on *Dalbergia Sissoo*, the conidia are about 52.5–102.5 $\times$ 12.5–28.8 μ in size, and in the form on *Celtis sinensis*, they are 45.6–57.6 $\times$ 14.4–18.0 μ in size. Further, in the latter, the number of spirals in less than in the former. Therefore, the present writer could not recognize these two forms as the same species.

In 1916, SAWADA found a small number of the perithecia of the fungus in question on *Celtis sinensis* collected by Y. FUJIKURO. These perithecia are entirely similar in character to those of Uncinula. For the above reasons, he established a new genus, Uncinulopsis. He transferred his *Phyllactinia subspiralis* to the new genus and named it, *Uncinulopsis subspiralis* SAWADA. The perithecial stage of this fungus had been named *Uncinula Shiraiana* by P. HENNINGS in 1901, and K. HARA transferred it to the Uncinulopsis of SAWADA in 1923.

On the other hand, the writer compared *Uncinulopsis Shiraiana* with *Uncinula polychaeta* on *Celtis mississippiensis* (Starkville, Miss. U.S.A. Oct. 1894, S. M. TRACY), on *Celtis occidentalis* (Starkville, Miss., Nov. 15, 1895, S. M. TRACY), and on *Celtis reticulata* (Georgtown, Texas, Aug. 27, 1909, F. D. HEALD & F. A. WOLF), and also with *Uncinula polychaeta* which was collected in this country, especially with those which were identified as *Uncinula polychaeta* by SALMON. The perithecia are entirely similar to those of Uncinula in

all these specimens, but the typical club shaped conidia were found on *Celtis occidentalis*. Also, in the form on *Celtis reticulata*, the inner mycelium was recognized. From the above mentioned facts, we may infer that polychaeta should be included in the genus Uncinulopsis. In the American *Uncinulopsis polychaeta* (B. & C.) HOMMA, the asci are cylindrical in shape, and the ascospores are elongate-oblong or cylindrical; the width of the asci and ascospores is narrower, the number of the ascospores is always 2, also the appendages are frequently remarkably flexuous, and more or less wider. *Uncinulopsis polychaeta* is easily distinguished from *Uncinulopsis Shiraiana*.

Subfam. Leveilluleae ARN.

Mycelium is endophytic, sending haustoria into the surrounding mesophyll cells of the leaf tissue. Matured conidia (Oidiopsis) are produced solitary on the conidiophores arising from the inner hyphae passing through the slits of the stomata.

One genus, Leveillula.

Leveillula ARN.

The perithecial stage of the genus has not yet been collected in this country.

In 1902, SCALIA (155) described a new genus Oidiopsis in Mucedinaceae. In this genus, the conidiophores are produced through the stomata from the inner mycelium, and the conidia are produced at the apex. The conidia are subclavate in shape. The form on *Asclepias curassavica* was included in this genus under the name of *Oidiopsis sicula* SCALIA.

In 1905 (144), SALMON published a paper on an endophytic species of the Erysiphaceae in which he noted on the endophytic habit of *Erysiphe taurica* parasitic on *Euphorbia lanata*, *Psoralea drupacea*, *Clematis songarica*, *Verbascum* sp., *Odontospermum aquaticum* and *Nepeta podostachys*. In 1906, (145) he determined that the conidial stage of *Erysiphe taurica* belongs to Oidiopsis. He found that *Oidium gigasporium* on *Ballota rupestris* is really the conidial stage of *E. taurica* proved by the presence of the perithecial stage of the fungus on *Ballota rupestris*, and moreover such a relation was confirmed by the discovery of the occurrence of both perithecial and conidial stages of *E. taurica* on many other host plants. SALMON transferred Oidiopsis from Mucedinaceae to Erysiphaceae, making necessary emendations on its characters and he changed *Erysiphe taurica* LÉV. to *Oidiopsis taurica* (LÉV.) SALM.

In 1921 (49), ARNAUD published his opinion, that the genus Oidiopsis ought to be retained as a genus of Mucedinaceae, as it is a case of Oidium. He therefore proposed a new genus Leveillula from the characters of the perithecial stage, and *Oidiopsis taurica* was included in this genus as *Leveillula taurica*.

Genus Oidiopsis was emended in the characters of the asco-stage by SALMON, but the writer wished to retain it as the name of the

conidial stage with Oidium and Ovulariopsis. We have followed in this paper the opinion of ARNAUD and accepted the name *Leveillula*.

This genus includes one species.

Leveillula taurica (LÉV.) ARNAUD

(Pl. XI, fig. 15)

Ann. d. Epiph. VII, p. 92, 1921; ŠKORIĆ, Erysiph. Croat. p. 56, 1926.

Syn. *Erysiphe taurica* LÉV. in DÉMIDOFF's Voy. Russ. Mérid. (bot.) p. 119, 1842, and Ann. Sci. Nat. III, 15, p. 161, 1851; SACC. Syll. Fung. I, p. 16, 1882; SALM. Monogr. Erysiph. p. 215, 1900, and Bull. Torr. Bot. Club, XXIX, p. 197, 1902; NEGER, Krypt. d. Mark Brand. VII, p. 115, 1905; KLIKA, Erysiph. Czechosl. p. 63, 1924.

Oidiopsis sicula SCALIA, Rendiconti del Congresso Bot. Palermo, p. 10, 1902; SACC. Syll. Fung. XVIII, p. 507, 1906.

Erysiphe Asterisci P. MAGN. Hedw. XLIV, p. 16, 1905.

Oidiopsis taurica (LÉV.) SALM. emend. Ann. Bot. XX, p. 187, 1906; FOËX, Ann. L'Ecole nat. d'Agric. Montp. VIII, p. 176, 1909; SAWADA, Agr. Exp. Stat. Formosa, Bull. IX, p. 77, 1914. (DOIDGE, Roy. Soc. South Afr. V, p. 243, 1915; SHIRAI & HARA, List, p. 237, 1927).

Hypophyllous, mycelium intercellular; conidiophores simple or branched, produced as special branches from the inner mycelium and sent out through the stomata; matured conidia solitary, cylindrical, clavate or elongate-ovate in shape, granulate, 50.4–72.0 × 14.4–21.6 μ. "Perithecia scattered or gregarious, usually more or less immersed in the persistent mycelium, large, 135–240 μ in diameter, usually about 200 μ, soon becoming concave, cells obscure; appendages usually very numerous, densely interwoven, rather short, more or less vaguely branched, colorless or brown, sometimes very short or even obsolete; asci 7–38, usually about 20, large, from narrowly cylindrical to ovate, usually long pedicellate, 75–110 (usually about 90) × 28–40 μ; spores 2, large, variable in size, usually about 32 × 18 μ, but varying from 28–40 × 14–22 μ, sometimes slightly curved." (Salm. Monogr. Erysiph. p. 216).

Hab. On leaves of *Capsicum annuum* L. (Togarashi). Formosa—Daihoku, Roshusho.

Distrib. Tropical and subtropical regions of the world.

Remarks. In 1824, the present species was published under the name of *Erysiphe taurica* by LÉVEILLÉ. Since then, for a long time this fungus was included in Erysiphe by all authors. In 1906, it was transferred to *Oidiopsis taurica* by SALMON, and in 1921, it was revised as *Leveillula taurica* by ARNAUD.

In 1933, K. SAWADA described two new species of *Oidiopsis Capsici* and *O. Papaveris*. The perithecial stage has not yet been found in either species. They will be treated here tentatively as the conidial stage of *Leveillula taurica*.

This species is widely distributed mostly in the tropics. The specimen which was kindly sent to Prof. MIYABE by Mr. K. SAWADA was in the conidial stage.

Conidial stages of Erysiphaceae

In the following four species, the perithecial stages have not yet been collected in this country.

Erysiphe Cinnamomi SAWADA

Agr. Exp. Stat. Formosa Bull. XIX, p. 144, 1919; HARA, Dendropath. p. 4, 1923.

Amphigenous, mostly hypophyllous, mycelium persistent or evanescent; conidiophores 20.4–55.2μ in length, matured conidia produced in a chain, ellipsoidal, granulate, 25.2–31.2 × 14.4–16.8μ.

Hab. On leaves of *Cinnamomum nominale* Hayata (Kusunoki-damashi). Formosa—Daito, Daihoku.

Remarks. SAWADA established the present species based on the characters of the conidial stage only. The present writer was able to examine the specimen of this species by his kindness, but she could not very well distinguish it from the conidial stage of *Erysiphe Cichoracearum*, as the conidia of *E. Cichoracearum* are widely variable in shape and size.

Microsphaera Mougeotii LÉV.

in P. HENN. Engl. Bot. Jahrb. XXXIV, p. 600, 1905. (SHIRAI, List, p. 55, 1905; SHIRAI & MIYAKE, List, p. 367, 1917; IDETA, Jap. Phytopath. p. 206, 1911; HARA, Dendropath. p. 14, 1923; SHIRAI & HARA, List, p. 217, 1927).

Amphigenous, mostly epiphyllous, mycelium persistent or evanescent; matured conidia produced in a chain, ellipsoidal, granulate, 24.0–26.4 × 14.4–15.6μ.

Hab. On leaves of *Lycium chinense* Mill. (Kuko). Honshu—Musashi, Inaba. Shikoku—Tosa.

Remarks. In 1905, the mildew on *Lycium chinense* which was collected in Kochi, May 14, 1902, by T. YOSHINAGA was identified as *Microsphaera Mougeotii* by P. HENNINGS. The co-type specimen was kindly sent us from Mr. YOSHINAGA. We examined the specimen carefully, but the perithecia could not be found on it. Perhaps, P. HENNINGS may have determined it by the characters of the conidial stage, although he said nothing about them. The numerous specimens of the present fungus collected in different parts of this country are all in the conidial stage and are lacking in the perithecial stage. The conidia of this fungus are produced in a perfect chain, showing that the fungus belongs to the genus *Erysiphe* rather than to *Microsphaera*.

Microsphaera Astragali (DC.) TREV.

in SAWADA, Agr. Exp. Stat. Formosa Bull. IX, p. 57, 1914; SHIRAI & MIYAKE, List, p. 365, 1917; SHIRAI & HARA, List, p. 216, 1927.

Amphigenous, mycelium evanescent or subpersistent, thinly effused; conidiophores 26.4–48.0 μ in length, matured conidia solitary, ellipsoidal or ovate, vacuolate, granulate, 28.0–43.2 × 12.0–20.4 μ in size.

Hab. On leaves of *Astragalus sinicus* L. (Genge). Honshu—Etchu, Bizen, Bitchu. Formosa—Daihoku.

Remarks. The writer could not distinguish whether the present fungus belongs to *Microsphaera Astragali* or *Erysiphe Pisi* by the conidial characters only, as both of these species have such similar characters in conidia.

Oidium Euonymi-japonicae (ARC.) SACC.

in SALM. Ann. Myc. III, p. 1, 1905; SACC. Syll. Fung. XVIII, p. 506, 1906, and Ann. Myc. VIII, p. 346, 1910; LIND. in RABENH. Krypt. Fl. Deutschl. IX, p. 726, 1910; LIND, Danish Fung. p. 165, 1913. (SHIRAI & HARA, List, p. 397, 1917).

Syn. *Oidium leucoconium* DESM. var. *evonymi-japonicae* ARCANG. Proc. Verb. Soc. Toscana Sci. Nat. XII, p. 108, 1900.

Microsphaera Euonymi-japonicae (SALM.) HARA, Bull. Agr. Soc. Shizuoka Prefecture, No. 282, p. 29–30, 1921.

Uncinula Euonymi-japonicae (SALM.) HARA, Dendropath. p. 22, 1923.

Amphigenous, mostly epiphyllous, mycelium persistent, forming dense white masses; conidiophores 39.2–75.0 μ in length, matured conidia solitary or in a chain, granulate, ellipsoidal in shape, 21.6–38.0 × 13.2–15.6 μ.

Hab. On leaves of *Euonymus japonicus* Thunb. (Masaki). Honshu—Musashi, Awa, Sagami, Echigo, Etchu, Suruga, Bitchu. Kyushu—Higo.

Remarks. In 1905, SALMON noted that the conidia are borne either singly at the apex of the conidiophore, or in chains of two or three. In 1921, K. HARA transferred it to *Microsphaera Euonymi-japonicae* (SALM.) HARA for the reason that the conidia are solitary and granulate and have no fibrosin bodies. In 1923, the same author noted it again under the name of *Uncinula Euonymi-japonicae*

(SALM.) HARA because of the conidial characters. In all Japanese specimens, the fungus is found always in the conidial stage as is in the case of Europe. The conidia are solitary, or two or three in a chain, as the apical conidium falls off more easily than in the case of other related species. Judging from the conidial characters, the fungus may most likely belong to Uncinula but it seems to the writer better to consider it as a species of Oidium, until its perithecial stage is collected.

Conclusion

General Part

1. The conidia are produced in the same way in all genera of Erysiphaceae, that is, in a chain. The conidia of Uncinula, Microsphaera, Erysiphe (Polygoni section), Phyllactinia, Uncinulopsis, and Leveillula have been thought to be produced solitarily at the tips of septated conidiophores. But two or three immature conidia are always found just under a matured spore.

2. In the structure of the perithecium, that of Cystotheca is most simple, and that of Uncinulopsis and Phyllactinia is most complex.

3. The perithecia of *Sphaerotheca fuliginea* parasitic on *Taraxacum ceratophorum* are produced on the hyphae originated from a single conidium.

4. When the conidia of *Erysiphe graminis* f. sp. *Tritici* were inoculated on the immune and susceptible varieties of wheat, the infection-tube produced from the appressorium of the germ-tube penetrated into the cell wall of the epidermis in both varieties. But, in the susceptible varieties, the haustoria were formed in the epidermal cells after two or three days from the inoculation, while in the immune varieties, they were never produced.

5. When the physiological condition of the host plant was divided into three stages of the growth, maturity and senility, the infection of the conidia did not take place in the early growing stage nor in the late senile stage, the mycelial growth was most vigorous in the mature stage, and the formation of perithecia generally took place in the early senile stage.

6. *Triticum dicoccum, Emmer* 3933, *T. dicoccum, Khapli* 6400, *T. boatum* and *Russian* No. 38 proved to be immune to *Erysiphe graminis* f. sp. *Tritici* which was collected in the experimental field of this University. Other species and varieties of wheat, which were used in the present experiments, proved to be either resistant or susceptible.

7. The susceptible and resistant varieties could be distinguished by the difference in the morphological characters of the leaf, such as the number of hairs on the surface of the leaf, and the thickness of the epidermal wall.

Systematic Part

8. In the present paper, the writer has reported on seventy-four species of Japanese powdery mildew fungi, belonging to eleven genera. Among them, *Microsphaera Ligustri, M. Coryli, M. Abeliae, M. Viciae-unijugae, Sawadaea Negundinis, Uncinula bifurcata, U. Picrasmae, U. Betulae* and *U. Nishidana* were added as new to science. Besides, as far as possible the conidial diagnoses have been added to the description of each species.

9. Each species was determined by its morphological characters and the species which were established because of the physiological characters were included under the original species as specialized forms.

10. In the determination of the species, numerous specimens collected in every part of this country were studied paying attention to variation in form and color and especially to the abnormal forms.

11. Cystotheca is regarded here as a genus belonging to the Erysiphaceae.

12. Japanese oak-mildew (*Microsphaera alphitoides*) is similar to the European oak-mildew and differs evidently from the American.

13. Typhulochaeta is the only genus endemic to Japan.

Host index

A

		PAGE
Abelia spathulata SIEB. & ZUCC.	*M. Abeliae*	392
Abelmoschus esculentus MOENCH.	*E. Polygoni*	328
Acalypha australis L.	*Sph. fuliginea*	304
Acer cissifolium C. KOCH.	*Saw. Aceris*	372
Acer cratagifolium SIEB. & ZUCC.	*Saw. Tulasnei*	374
Acer Mayrii GRAF. v. SCHW.	*Saw. Tulasnei*	375
Acer Miyabei MAXIM.	*Saw. Tulasnei*	374
Acer Negundo L.	*Saw. Negundinis*	376
Acer palmatum THUNB.	*Saw. Tulasnei*	375
Acer pictum THUNB.	*Saw. Tulasnei*	375
Acer ukurunduense TRAUTV. & MEY.	*Saw. Tulasnei*	375
Achillea Millefolium L.	*E. Cichoracearum*	339
Achillea ptarmicoides MAXIM.	*E. Cichoracearum*	339
Achillea sibirica LEDEB.	*E. Cichoracearum*	339
Aconitum Fischeri REICHB.	*E. Aquilegiae*	331
Aconitum gigas LÉV. & VNT.	*E. Aquilegiae*	331
Aconitum japonica THUNB.	*E. Aquilegiae*	331
Aconitum kamtschaticum WILLD.	*E. Polygoni*	328
Aconitum yezoense NAKAI	*E. Aquilegiae*	331
Actaea acuminata WALL.	*E. Aquilegiae*	331
Actinidia arguta PLANCH.	*Phyl. Fraxini*	411
	U. Actinidiae	354
Actinidia formosana HAY.	*Phyl. Actinidiae-formosonae*	414
Actinidia Kolomikta MAXIM.	*U. Actinidiae*	354
Actinidia latifolia Nakai	*Phyl. Actinidiae-latifoliae*	417
Actinidia polygama MAXIM.	*Phyl. Fraxini*	411
	U. Actinidiae	354
Actinostemma lobatum MAXIM. var. racemosum MAK.	*E. Polygoni*	329
Adenocaulon bicolor HOOK. var. adhaerescens MAK.	*Sph. fuliginea*	304
Adenophora Thunbergiana KUDO	*E. Cichoracearum*	339
Aeschynomene indica L.	*E. Pisi*	323
Agastache rugosa O. KUNTZE	*Oidium*	343
Agastache rugosa O. KUNTZE var. hypoleuca KUDO	*Oidium*	343
Agrimonia pilosa LEDEB.	*Sph. Humuli*	297
Agropyrum ciliare FRANCK.	*E. graminis*	334
Agropyrum repens BEAUV.	*E. graminis*	334
Ajuga ciliata BUNGE	*Sph. fuliginea*	304
Ajuga yezoensis MAXIM.	*Sph. fuliginea*	304

		Page
Akebia lobata DECNE	*M. Alni*	381
Akebia quinata DECNE	*M. Alni*	381
Alangium platanifolium BAILL. var. macrophyllum WAG.	*Oidium*	369
Alnus alnobetula HARTIG var. fruticosa WINKL.	*Phyl. Fraxini*	410
Alnus cylindrostachys MAKINO	*U. Miyabei*	365
Alnus formosana (BURK.) MAKINO	*Ovulariopsis*	418
Alnus hirsuta TURCZ.	*M. Alni*	380
	Phyl. Fraxini	410
	U. Miyabei	365
Alnus hirsuta TURCZ. var. sibirica SCHNEID.	*Phyl. Fraxini*	410
	U. Miyabei	365
Alnus japonica SIEV. & ZUCC.	*Phyl. Fraxini*	410
	U. Miyabei	365
Alnus japonica SIEV. & ZUCC. var. arguta CALL.	*Phyl. Fraxini*	410
	U. Miyabei	365
Alnus koreana NAKAI	*Phyl. Fraxini*	410
Alnus obtusata MAKINO	*Phyl. Fraxini*	410
Alnus pendula MATSUM.	*E. Aquilegiae*	331
	E. Pisi	323
	U. Miyabei	365
Amelanchier asiatica ENDL.	*Phyl. corylea*	406
Ampelopsis heterophylla SIEB. & ZUCC.	*U. necator*	368
	Ovulariopsis	418
Ampelopsis heterophylla SIEB. & ZUCC. var. ciliata NAKAI	*Ovulariopsis*	418
Angelica Miqueliana MAXIM.	*E. Heraclei*	326
Aphananthe aspera PLANCH.	*U. Clintonii*	345
Aquilegia flabellata SIEB. & ZUCC.	*E. Aquilegiae*	331
Aquilegia flabellata SIEB. & ZUCC. var. pumila KUDO	*E. Aquilegiae*	332
Arabis pendula L.	*E. Cichoracearum*	338
Arctium Lappa L.	*Sph. fuliginea*	305
Arnica sachalinensis A. GR.	*Sph. fuliginea*	305
Artemisia japonica THUNB.	*E. Cichoracearum*	339
Artemisia japonica THUNB. var. desertorum MAXIM.	*E. Cichoracearum*	339
Artemisia vulgaris L. var. indica MAXIM.	*E. Cichoracearum*	339
Artemisia vulgaris L. var. kamtschatica BESS.	*E. Cichoracearum*	339
Artemisia vulgaris L. var. latiloba LEDEB.	*E. Cichoracearum*	339
Aruncus silvester Kostel. var. americana MAXIM.	*Sph. Humuli*	297

		PAGE
Aruncus silvester Kostel. var. vulgaris MAXIM.	*Sph. Humuli*	297
Asclepias curassavica L.	*Ovulariopsis*	418
Aster Laulureanus FRANCH.	*E. Cichoracearum*	339
Aster pinnatifidus MAKINO	*Sph. fuliginea*	305
Aster tataricus L. f.	*Sph. fuliginea*	305
Astilbe Thunbergii MIQ.	*Sph. Humuli*	297
Astilbe Thunbergii MIQ. var. congesta BOISS.	*Sph. Humuli*	297
Astragalus reflexistipulus MIQ.	*E. Pisi*	323
Astragalus secundus DC.	*E. Pisi*	323
Astragalus sinicus L.	*Oidium*	425

B

Benincasa hispida COGN.	*Sph. fuliginea*	304
Berberis amurensis RUPR.	*M. Berberidis*	395
Berberis Regeliana KOEHNE	*M. Berberidis*	395
Berberis Thunbergii DC. var. Maximowiczii FRANCH. & SAV.	*M. Berberidis*	395
Berchemia racemosa SIEB. & ZUCC.	*M. Alni*	380
Beta vulgaris L. var. Rapacea C. KOCH.	*Oidium*	342
Betula Ermanii CHAM. var. subcordata KOIDZ.	*U. Betulae*	362
Betula Tauschii KOIDZ.	*U. Betulae*	362
	Phyl. Fraxini	410
Bidens bipinnata L.	*Sph. fuliginea*	305
Bidens pilosa L.	*Sph. fuliginea*	305
Bidens pilosa L. var. albiflora MAXIM.	*Sph. fuliginea*	305
Bidens radiata THUILL.	*Sph. fuliginea*	305
Bidens tripartita L.	*Sph. fuliginea*	305
Brachypodium miserum KOIDZ.	*E. graminis*	334
Brassica campestris L. var. rapifera METZG.	*E. Cichoracearum*	338
Bromus japonicus THUNB.	*E. graminis*	334
Broussonetia Kaempferi SIEB.	*Phyl. moricola*	408
Broussonetia Kazinoki SIEB.	*Phyl. moricola*	408
Broussonetia papyrifera VENT.	*Ovulariopsis*	418
Brunella vulgaris L.	*Oidium*	343

C

Cacalia auriculata DC. var. kamtschatica KOIDZ.	*Sph. fuliginea*	305
Cacalia auriculata DC. var. ochotensis KOM.	*Sph. fuliginea*	305
Cacalia delphinifolia SIEB. & ZUCC.	*E. Polygoni*	329

		PAGE
Cacalia hastata L. var. glabra LEDEB.	Sph. fuliginea	305
Cacalia hastata L. var. pubescens LEDEB.	Sph. fuliginea	305
Caesalpinia japonica SIEB. & ZUCC.	Phyl. corylea	406
Caltha palustris L. var. gigas LÉV.	E. Aquilegiae	332
Caltha palustris L. var. procumbens BECK.	E. Aquilegiae	332
Caltha palustris L. var. sibirica REGEL f. decumbens MAKINO	E. Aquilegiae	332
Capsicum annuum L.	Lev. taurica	423
Cardamine flexiosa WITH.	E. Cichoracearum	338
Carica Papaya L.	Ovulariopsis	418
Carpesium abrotanoides L. var. Thunbergianum MAKINO	Sph. fuliginea	305
Carpesium trista MAXIM.	Sph. fuliginea	305
Carpinus laxiflora BL.	U. carpinicola	363
Castanea crenata SIEB. & ZUCC.	M. Alni	380
	Phyl. quercus	415
Cedrela sinensis JUSS.	U. Delavayi	349
Celastrus articulata THUNB.	U. Sengokui	351
Celtis sinensis PERS.	U. Clintonii	345
	Uncinulop. Shiraiana	419
Cephalanthus occidentalis L.	Oidium	369
	Ovulariopsis	418
Chelonopsis longipes MAKINO	E. Galeopsidis	342
Chelonopsis moschatus MIQ.	E. Galeopsidis	342
Chrysanthemum Marschalii ASCHERS.	E. Cichoracearum	339
Chrysanthemum sinense SABIN. var. hortense MAKINO	E. Cichoracearum	339
Chrysosplenium flagelliferum FR. SCHM.	Oidium	343
Cinnamomum nominale HAYATA	Oidium	424
Cirsium arvense SCOP. var. setosum LEDEB.	Sph. fuliginea	305
Cirsium Buergeri MIQ. var. Albrechtii NAKAI	Sph. fuliginea	305
Cirsium Grayanum NAKAI	E. Aquilegiae	332
	Sph. fuliginea	305
Cirsium pendulum FISCH.	Sph. fuliginea	305
Cirsium schantarense TRAUTV. & MEY.	E. Aquilegiae	332
Cirsium Weyrichii MAXIM.	E. Aquilegiae	332
	E. Cichoracearum	339
	Sph. fuliginea	305
Clematis alpina MILL.	E. Polygoni	328
Clematis fusca TURCZ. var. mandshurica TAKEDA	E. Polygoni	328
Clematis paniculata THUNB.	E. Polygoni	328
Clerodendron trichotomum THUNB.	Sph. Humuli	298
Clinopodium chinensis KUNTZE	E. Polygoni	328
	Sph. fuliginea	304

		Page
Clinopodium chinensis KUNTZE var. macrantha MAKINO	*Sph. fuliginea*	304
Clinopodium sachalinense KOIDZ.	*E. Polygoni*	328
Cocculus trilobus DC.	*M. Alni*	381
	M. Pseudo-Lonicerae	394
Cornus controversa HEMSL.	*M. Alni*	381
Cornus Kousa BUERG.	*M. Alni*	381
Corydalis ochotensis TURCZ.	*Sph. Humuli*	297
Corylus heterophylla FISCH.	*M. Coryli*	389
Corylus heterophylla FISCH. var. japonica KOIDZ.	*M. Coryli*	389
Corylus mandshurica MAXIM.	*M. Coryli*	389
	Phyl. corylea	406
Corylus Sieboldiana BL.	*M. Coryli*	389
	Phyl. corylea	406
Cosmos bipinnatus CAV.	*Sph. fuliginea*	305
Crataegus chlorosarca MAXIM.	*P. Oxyacanthae*	319
Crataegus jozana SCHNEID.	*P. Oxyacanthae*	319
Crataegus Maximowiczii SCHNEID.	*P. Oxyacanthae*	319
Cucumis Melo L.	*Sph. fuliginea*	304
Cucumis sativus L.	*Sph. fuliginea*	304
Cucurbita moschata DUCH. var. melonaeformis MAKINO	*Sph. fuliginea*	304
Cucurbita moschata DUCH. var. Toonas MAKINO	*Sph. fuliginea*	304
Cydonia sinensis THOUIN	*Phyl. corylea*	406
Cynanchum caudatum MAXIM.	*Sph. fuliginea*	304
Cynanchum yezoense NAKAI	*Sph. fuliginea*	304

D

Dahlia variabilis DESF.	*Sph. fuliginea*	305
Desmodium caudatum DC. var. japonicum NAKAI	*E. Pisi*	323
Diervilla decora NAKAI	*E. Pisi*	323
Diervilla japonica DC.	*E. Pisi*	323
Dicliptera japonica MAK.	*Sph. fuliginea*	304
Diospyros Kaki L. f.	*Phyl. kakicola*	412
Diospyros Lotus L.	*Phyl. kakicola*	412
Draba borealis DC. var. kurilensis FR. SCHEM.	*Oidium*	313

E

Elodes japonica BL.	*Oidium*	343
Elsholtzia patrini GARCKE	*E. Polygoni*	328
Elymus mollis TRIN.	*E. graminis*	334

		PAGE
Epilobium Behringianum HAUSSKN.	*Sph. Epilobii*	301
Epilobium cephalostigma HAUSSKN.	*Sph. Epilobii*	301
Epilobium glandulosum LEHM.	*Sph. Epilobii*	301
Epilobium montanum L.	*Sph. Epilobii*	301
Epilobium palustre L.	*Sph. Epilobii*	301
Epilobium pyrricholophum FR. & SAV.	*Sph. Epilobii*	301
Erigeron acre L. var. hirsutum FR. SCHM.	*Sph. fuliginea*	305
Erigeron canadensis L.	*Sph. fuliginea*	305
Euonymus japonica THUNB.	*Oidium*	425
Euphorbia Sieboldiana MORR. & DECNE	*Oidium*	313
Euphrasia Maximowiczii WETTST.	*Sph. fuliginea*	304
Eupatorium Fortunei TURCZ. var. *simplicifolium* NAKAI	*Sph. fuliginea*	305

F

Fagopyrum esculentum MOENCH.	*E. Heraclei*	326
Fagus japonica MAXIM.	*U. curvispora*	360
Falcata japonica KOM.	*E. Pisi*	323
Fatoua pilosa GAUD. var. subcordata BUREAU	*Sph. fuliginea*	303
Filipendula ciliata KUDO	*Sph. Humuli*	297
Filipendula kamtshatica MAXIM.	*Sph. Humuli*	298
Filipendula palmata MAXIM.	*Sph. Humuli*	298
Fragalia chiloensis DUCH. var. ananassa BAILEY	*Sph. Humuli*	298
Fragalia neglecta LINDEM.	*Sph. Humuli*	298
Fraxinus japonica BL.	*T. japonica*	370
	U. Fraxini	364
	U. Salmoni	352
Fraxinus longicuspis SIEB. & ZUCC.	*U. Fraxini*	364
	U. Salmoni	352
Fraxinus mandshurica RUPR.	*Phyl. Fraxini*	411
	U. Fraxini	364
	U. Salmoni	352
Fraxinus ornus L.	*U. Salmoni*	352
Fraxinus pubinervis BL.	*Phyl. Fraxini*	411
Fraxinus Sieboldiana BL.	*Phyl. Fraxini*	411
	U. Fraxini	364
	U. Salmoni	352
Fraxinus Sieboldiana BL. var. pubescens KOIDZ.	*U. Salmoni*	352

G

Galeopsis Tetrahit L.	*E. Galeopsidis*	342
Galium Aparine L.	*E. Cichoracearum*	339

		Page
Galium verum L. var. lacteum MAXIM.	*E. Cichoracearum*	339
Galium verum L. var. typicum MAXIM.	*E. Cichoracearum*	339
Geranium erianthum DC.	*E. Galeopsidis*	342
	Sph. Humuli	298
Geranium nepalense SWEET	*E. Galeopsidis*	342
Geranium nepalense SWEET var. Thunbergii KUDO	*Sph. Humuli*	298
Geranium sibiricum L.	*E. Galeopsidis*	342
	Sph. Humuli	298
Geranium yezoense FRANCK. & SAV.	*E. Galeopsidis*	342
	Sph. Humuli	298
Geranium yezoense FR. & SAV. var. nipponicum NAKAI	*Sph. Humuli*	298
Gerbera Anandria SCH. BIP.	*Sph. fuliginea*	305

H

Halorrhagis micrantha R. BR.	*Sph. fuliginea*	304
Hamamelis japonica SIEB. & ZUCC.	*Phyl. corylea*	406
Helianthus annuus L.	*Sph. fuliginea*	305
Helianthus tuberosus L.	*Sph. fuliginea*	306
Heliotropium indicum L.	*Oidium*	313
Helwingia japonica DIETER	*M. Alni*	381
Hordeum sativum JESS. var. hexastichon L.	*E. graminis*	334
Hordeum sativum JESS. Var. vulgare HACK.	*E. graminis*	334
Hovenia dulcis THUNB. var. glabra MAKINO	*M. Yamadai*	390

I

Impatiens Balsamina L.	*Sph. fuliginea*	304
Impatiens Noli-tangere L.	*Sph. fuliginea*	304
Impatiens Textori MIQ.	*Sph. fuliginea*	304
Indigofera pseudo-tinctoria MATSUM.	*E. Pisi*	323
Indigofera tinctoria L.	*E. Pisi*	323
Inula salicina L.	*E. Ciehoracearum*	339

J

Juglans Sieboldiana MAXIM.	*M. Yamadai*	390
	Phyl. Fraxini	410

L

Lactuca dentata MAKINO var. Thunbergii MAKINO	*Sph. fuliginea*	306

		Page
Lactuca denticulata MAX. var. typica MAXIM.	*Sph. fuliginea*	306
Lactuca laciniata MAKINO	*Sph. fuliginea*	306
Lactuca laciniata MAKINO var. indivisa MAKINO	*Sph. fuliginea*	306
Lactuca Raddeana MAXIM.	*Sph. fuliginea*	306
Lactuca Scariola L. var. integrata GREN. & GOD.	*Sph. Humuli*	298
Lactuca sibirica BENTH.	*Sph. fuliginea*	306
Lagenaria vulgaris SER.	*Sph. fuliginea*	304
Lagerstroemia indica L.	*U. australiana*	350
Lagotis glauca GAERTN.	*Sph. fuliginea*	304
Lamium album L. var. barbatum FR. & SAV.	*E. Galeopsidis*	342
Laportea bulbifera WEDD.	*E. Cichoracearum*	338
Lathyrus maritimus BIGEL.	*E. Pisi*	323
Lespedeza bicolor TURCZ. var. japonica NAKAI	*E. Pisi*	323
Lespedeza cuneata G. DON.	*E. Pisi*	323
Lespedeza pilosa SIEB. & ZUCC.	*E. Pisi*	323
Lespedeza virgata DC.	*E. Pisi*	323
Ligularia sibirica GASS. var. speciosa DC.	*Sph. fuliginea*	306
Ligularia stenocephala MATSUM.	*E. Galeopsidis*	342
Ligustrum ovalifolium HASSK.	*M. Ligustri*	386
Lindera praecox BL.	*M. Alni*	381
Linum usitatissimum L.	*E. Polygoni*	328
Lonicera Chamissoi BUNGE	*M. Alni*	381
Lonicera ciliata MUHL.	*M. Alni*	381
Lonicera japonica THUNB.	*M. Lonicerae*	393
Lonicera Maackii HERD.	*M. Alni*	381
Lonicera Morrowii A. GRAY	*M. Alni*	381
Lonicera orientalis LAM.	*M. Alni*	381
Lonicera tatarica L.	*M. Alni*	381
Lotus corniculatus L. var. japonicus REGEL	*E. Pisi*	323
Lupinus perennis L.	*E. Pisi*	323
Lycium chinense MILL.	*Oidium*	424
Lycopus lucidus TURCZ. var. genuinus HERD.	*E. Galeopsidis*	342
Lythrum Salicaria L.	*E. Polygoni*	328

M

Macaranga Tanarius (L.) MUALL. ARG.	*Ovulariopsis*	418
Macleya cordata R. BR.	*E. Polygoni*	328
Magnolia obovata THUNB.	*M. diffusa*	398
Magnolia praecocissima KOIDZ.	*Phyl. Fraxini*	410
Magnolia praecocissima KOIDZ. var. borealis KOIDZ.	*Phyl. Fraxini*	410

		Page
Mahonia Fortunei FEDDE	*Oidium*	402
Malus baccata Borckh. var. mandshurica SCHNIED.	*P. leucotricha*	315
Malus pumila MILL. var. domestica SCHNEID.	*P. leucotricha*	315
Matricaria Chamomilla L.	*E. Cichoracearum*	339
Medicago lupulina L.	*E. Pisi*	323
Melothria japonica MAXIM.	*Sph. Humuli*	298
Microlespedeza stipulacea MAKINO	*E. Pisi*	323
Mimulus inflatus NAKAI	*E. Polygoni*	329
Morus bombycis KOIDZ.	*Phyl. moricola*	408
	U. Mori	366

N

Nepeta Glechoma BENTH.	*Sph. fuliginea*	304
Nepeta subsessilis MAXIM.	*Sph. fuliginea*	304
Nicotiana alata LINK & OTTO	*E. Cichoracearum*	338
Nicotiana Tabacum L.	*E. Cichoracearum*	338

O

Ostrya japonica SARG.	*M. Alni*	280
	Phyl. corylea	406
Oxalis corniculata L.	*M. Russellii*	402

P

Paeonia albiflora PALL. var. hortensis MAK.	*E. Aquilegiae*	332
Paeonia japonica MIYABE & TAKEDA	*E. Aquilegiae*	332
Palura paniculata NAKAI var. pilosa NAKAI	*M. divaricata*	388
Pasania cuspidata OERST.	*C. Wrightii*	291
Pasania Sieboldii MAKINO	*M. alphitoides*	384
Paulownia tomentosa STEUD.	*Phyl. imperialis*	416
Pedicularis euphrasioides STEPH.	*Sph. fuliginea*	304
Pedicularis japonica MIQ. var. Maximowiczii NAKAI	*Sph. fuliginea*	304
Pedicularis resupinata L.	*Sph. fuliginea*	304
Petasites japonica MIQ.	*Sph. fuliginea*	306
Peucedanum terebinthaceum FISCH.	*E. Heraclei*	326
Phaseolus Mungo L.	*E. Pisi*	323
Phaseolus radiatus L. var. aurea PRAIN.	*E. Pisi*	323
	Sph. fuliginea	303
Phtheirospermum japonicum KANITZ.	*Sph. fuliginea*	304
Physaliastrum echinatum MAK.	*E. Cichoracearum*	338
Physalis Francheti MAST. var. Bunyardii MAKINO	*E. Cichoracearum*	338

		Page
Picrasma quassioides BENN.	*M. Alni*	381
	Phyl. corylea	406
	U. Picrasmae	353
Picris hieracioides L. var. japonica REGEL	*E. Cichoracearum*	339
Pilea viridissima MAKINO	*E. Polygoni*	328
Pirus communis L.	*Phyl. Pyri*	413
Pirus sinensis LINDL. var. culta MAKINO	*Phyl. Pyri*	413
Pisum sativum L.	*E. Pisi*	323
Plantago kamtschatica LINK.	*E. Cichoracearum*	338
Plantago lanceolata L.	*E. Cichoracearum*	338
Plantago major L. var. asiatica DECNE	*E. Cichoracearum*	338
Plectranthus glaucocalyx MAXIM. var. japonicus MAKINO	*E. Galeopsidis*	342
Plectranthus inflexus VOHL.	*Oidium*	313
Poa annua L.	*E. graminis*	334
Poa pratensis L.	*E. graminis*	334
Poa sphondylodes TRIN. var. strictula KOIDZ.	*E. graminis*	334
Polemonium coeruleum L. var. laxiflorum MIYABE & MIYAKE	*E. Cichoracearum*	338
Polemonium coeruleum L. var. racemosum MIYABE & KUDO	*E. Cichoracearum*	338
Polemonium coeruleum L. var. saxiflorum MIYABE & MIYAKE	*Sph. Humuli*	298
Polemonium coeruleum L. var. yezoense MIYABE & KUDO	*E. Cichoracearum*	338
Populus Maximowiczii A. HENRY	*U. Salicis*	357
Populus Sieboldii MIQ.	*U. Salicis*	357
Potentilla centigrana MAXIM.	*Sph. Humuli*	298
Potentilla fragarioides L. var. Sprengeliana MAXIM.	*Sph. Humuli*	298
Potentilla Freyniana BORNM.	*Sph. Humuli*	298
Polygonum aviculare L.	*E. Polygoni*	328
Prunus Armeniaca L. var. Ansu MAXIM.	*P. tridactyla*	317
Prunus Buergeriana MIQ.	*P. tridactyla*	317
Prunus Cerasus L.	*P. tridactyla*	317
Prunus Grayana MAXIM.	*P. tridactyla*	317
Prunus Mume SIEB. & ZUCC.	*P. tridactyla*	317
Prunus padus L.	*P. tridactyla*	317
Prunus Persica SIEB. & ZUCC. var. vulgaris MAXIM.	*P. tridactyla*	317
Prunus serrulata LINDL. var. albida MAKINO subv. speciosa MAKINO	*P. tridactyla*	317
Prunus triflora ROXB.	*P. tridactyla*	317
Prunus yedoensis MATSUM.	*P. tridactyla*	317

Q

Quercus acuta THUNB. .... *C. Wrightii* 291
Quercus acutissima CARR. .... *C. lanestris* 293
M. alphitoides 384
Quercus alba L. .... *M. alphitoides* 384
M. calocladophora 383
Quercus aliena BL. .... *C. lanestris* 293
T. japonica 370
Quercus crispula BL. .... *C. lanestris* 293
M. alphitoides 385
T. japonica 370
Quercus dentata THUNB. .... *C. lanestris* 293
M. alphitoides 385
Quercus gilva BL. .... *M. alphitoides* 385
Quercus glauca THUNB. .... *C. Wrightii* 291
E. Heraclei 326
M. alphitoides 385
Quercus major NAKAI .... *C. lanestris* 293
Quercus mongolica FISCH. .... *M. alphitoides* 385
Quercus myrsinaefolia BL. .... *C. Writhtii* 291
E. Heraclei 326
M. alphitoides 385
Quercus phylliraeoides A. GRAY .... *M. alphitoides* 385
Quercus Robur L. .... *M. alphitoides* 385
Quercus serrata THUNB. .... *C. lanestris* 293
M. alphitoides 385
Phyl. quercus 415
T. japonica 370
U. bifurcata 360
U. septata 361
Quercus stenophylla MAKINO .... *C. Wrightii* 292
E. Heraclei 326
M. alphitoides 385
Quercus variabilis BL. .... *Phyl. quercus* 415
Quercus Vibreyana FR. & SAV. .... *M. alphitoides* 385

R

Ranunculus acris L. var. Steveni REGEL .... *E. Aquilegiae* 332
Ranunculus japonicus LANGSD. .... *E. Aquilegiae* 332
Ranunculus repens L. .... *E. Aquilegiae* 332
Raphanus sativus L. .... *E. Cichoracearum* 338
Rhamnus dahurica PALL. var. nipponica
MAKINO .... *M. Alni* 381
Rhododendron Albrechtii MAXIM. .... *Phyl. corylea* 406
Rhododendron macrocepalum MAXIM. .... *M. Alni* 381
Rhus japonica L. .... *U. verniciferae* 355

		Page
Rhus *succedanea* L.	*U. verniciferae*	355
Rhus sylvestris Sieb. & Zucc.	*U. verniciferae*	355
Rhus Toxicodendron L. var. vulgaris Pursh. f. radicans Engl.	*U. verniciferae*	355
Rhus trichocarpa Miq.	*U. verniciferae*	355
Rhus vernicifera DC.	*U. verniciferae*	355
Ribes Grossularia L.	*Sph. Mors-Uvae*	309
Robinia pseudacacia L.	*M. Bäumleri*	399
Rosa acicularis Lindl. var. Gmelini C. K. Schn.	*Sph. pannosa*	313
Rosa chinensis Jacq.	*Sph. pannosa*	313
Rosa indica L. *var. formosana* Hay.	*Oidium*	369
Rosa Marretii Lév.	*Sph. pannosa*	313
Rosa multiflora Thunb.	*Sph. pannosa*	313
	U. simulans	359
Rosa sp. (cult.)	*Sph. pannosa*	313

S

Salix Bakko Kimura	*U. Salicis*	357
Salix Gilgiana Seemen.	*U. Salicis*	357
Salix glandulosa Seem. var. Warburgi (Seem.) Koidz.	*Ovulariopsis*	418
Salix gracilistyla Miq.	*U. Salicis*	357
Salix Hultenii Flod. var. angustifolia Kimura	*U. Salicis*	357
Salix integra Thunb.	*U. Salicis*	357
Salix Lackschewitziana Toepffer	*U. Salicis*	357
Salix purpurea L.	*U. Salicis*	357
Salix sachalinensis Fr. Schm.	*U. Salicis*	357
Salix Sieboldiana Bl.	*U. Salicis*	357
Sambucus Buergeriana Bl. var. Miquelii Nakai	*M. Grossulariae*	397
Sambucus Sieboldiana Bl. var. typica Nakai	*M. Grossulariae*	397
Sanguisorba canadensis L. var. media Maxim.	*Sph. Humuli*	298
Sanguisorba officinalis L.	*Sph. Humuli*	298
Sanguisorba officinalis L. var. carnea Regel.	*Sph. Humuli*	298
Sanguisorba tenuifolia Fisch. var. alba Trautv.	*Sph. Humuli*	298
Sapium sebiferum Roxb.	*Phyl. corylea*	406
Saussurea manshurica Kom.	*Sph. fuliginea*	306
Saxifraga cortusaefolia Sieb. & Zucc. var. typica Makino	*E. Polygoni*	328
Saxifraga fusca Maxim.	*Sph. fuliginea*	303
Saxifraga reflexa Hook. *f.*	*Sph. fuliginea*	303

		PAGE
Schizandra chinensis BAILL.	*M. Alni*	381
Schizandra nigra MAXIM.	*M. Alni*	381
Schizopepon bryoniaefolius MAXIM.	*E. Polygoni*	329
Schizophragma hydrangeoides SIEB. & ZUCC.	*Phyl. Fraxini*	410
Scopolia japonica MAXIM.	*E. Cichoracearum*	338
Schorzonera radiata FISCH.	*E. Cichoracearum*	339
Scutellaria dependens MAXIM.	*E. Polygoni*	329
Scutellaria galericulata L. var. pubescens REGEL	*E. Polygoni*	329
Scutellaria scordifolia Fisch. f. puberula KOM.	*E. Polygoni*	329
Scutellaria strigillosa HEMSL.	*E. Polygoni*	329
Scutellaria ussuriensis KUDO	*E. Polygoni*	329
Securinega fluggeoides MUELL. ARG.	*M. Euphorbiae*	392
Sedum Aizoon L.	*E. Polygoni*	328
Sedum alboroseum BAK.	*E. Polygoni*	328
Sedum Telephium L. var. purpureum L.	*E. Polygoni*	328
Senecio Cineraria DC.	*Sph. fuliginea*	306
Senecio nemorensis L. var. Fucksii KOCH.	*Sph. fuliginea*	306
Senecio sonchifolia MOENCH.	*Oidium*	313
Serratula coronata L.	*E. Cichoracearum*	338
Sesamum indicum L.	*Oidium*	343
Seseli Libanotis KOCH.	*E. Heraclei*	326
Siegesbeckia pubescens L.	*Sph. fuliginea*	306
Sophora angustifolia SIEB. & ZUCC.	*E. Pisi*	323
Solanum Melongena L.	*E. Cichoracearum*	338
Solanum nigrum L.	*E. Cichoracearum*	338
Solidago Virgaurea L.	*E. Cichoracearum*	339
Sonchus arvensis L. var. uliginosus TRAUTV.	*E. Cichoracearum*	339
Sonchus asper VILL.	*E. Cichoracearum*	339
Sonchus oleraceus L.	*E. Cichoracearum*	339
	Sph. fuliginea	306
Spiraea betulifolia PALL.	*P. Oxyacanthae*	319
Spiraea prunifolia S. & Z. var. plena SCHNEID.	*Sph. Humuli*	298
Spiraea salicifolia L. var. lanceolata TORR. & GRAY	*P. Oxyacanthae*	320
Spiraea Thunbergii SIEB.	*Sph. Humuli*	298
Stachys baicalensis FISCH. var. hispida NAKAI	*E. Galeopsidis*	342
Stachys baicalensis FISCH. var. hispidula NAKAI	*E. Galeopsidis*	342
Staphylea Bumalda SIEB. & ZUCC.	*M. Alni*	381
Stephanandra incisa ZABEL.	*Sph. japonica*	311
Sterculia platanifolia L.	*U. Nishidana*	367
Stipa sibirica LAM. var. japonica HACK.	*E. graminis*	335

		Page
Styrax japonicum SIEB. & ZUCC.	*M. Alni*	381
Styrax Obassia SIEB. & ZUCC.	*U. geniculata*	362
Syringa japonica DECNE	*M. Alni*	380

T

Tanacetum vulgare L.	*E. Cichoracearum*	339
Taraxacum ceratophorum DC.	*Sph. fuliginea*	306
Taraxacum officinale WEB.	*Sph. fuliginea*	306
Thalictrum akanense HUTH.	*E. Aquilegiae*	332
Thalictrum Thunbergii NAKAI	*E. Aquilegiae*	332
Thermopsis fabacea DC.	*E. Pisi*	323
Tilia japonica SIMK.	*U. Miyabei*	365
	U. Clintonii	345
Tilia Maximowicziana SHIRASAWA	*U. Miyabei*	365
Toisusu Urbaniana KIMURA	*U. Salicis*	357
Torilis Anthriscus BERNK.	*E. Heraclei*	326
Trichosanthes cucumeroides MAXIM.	*E. Polygoni*	329
Trifolium incarnatum L.	*E. Pisi*	323
Trifolium repens L.	*E. Pisi*	323
Trisetum flavescens BEAUV. var. genuinum HACK.	*E. graminis*	335
Triticum sativum LAM. var. vulgare HACK.	*E. graminis*	335

U

Ulmus laciniata MAYR.	*U. clandestina*	348
Ulmus parvifolia JACQ.	*U. clandestina*	348
Ulnus *propinqua* KOIDZ.	*P. spiralis*	318
	U. clandestina	348

V

Veronica Grayi MIYABE & KUDÔ	*Sph. Humuli*	298
Veronica sibirica L.	*Sph. Humuli*	298
Veronica virginica L. var. japonica NAKAI	*Sph. Humuli*	298
Vicia Cracca L. var. japonica MIQ.	*M. Bäumleri*	399
Vicia japonica A. GRAY	*M. Bäumleri*	399
Vicia nipponica MATSUM.	*M. Bäumleri*	399
Vicia Tanakae FR. & SAV.	*M. Viciae-unijugae*	401
Vicia unijuga AL. BR.	*M. Viciae-unijugae*	401
Vigna sinensis SAV.	*E. Pisi*	323
Vitis vinifera L.	*U. necator*	368

Z

Zelkowa serrata MAK.	*U. Zelkowae*	347

Literature cited

General Part

1. BEZSSONOFF, N.: Quelques nouveaux faits concernant le formation du périthèce et la délimitation des ascospores chez les Erysiphacées. Bull. Soc. Myc. France, XXX, 406–415, 1914.
2. BLACKMAN, V. H. & FRASER, H. C. L.: Fertilization in Sphaerotheca. Ann. Bot. XIX, 567–569, 1905.
3. CLAUSSEN, P.: Über neuere Arbeiten zur Entwickelungsgeschicht der Ascomyceten. (Sammelreferate). Ber. Deutsch. Bot. Gesell. XXIV, 11–38, 1906.
4. DE BARY, A.: Über die Fruchtentwickelung der Ascomyceten. 1863.
5. ————: Beiträge zur Morphologie und Physiologie der Pilze. I, xiii, 23–52, 1870.
6. DANGEARD, P. A.: L'origine du périthèce chez les Ascomycètes. Botaniste, X, 216–243, 1907.
7. DELACROIX, G.: Travaux de la Station de pathologie végétale: sur le "blance" des feuilles de Mûrier de Madagascar produit par *Ovulariopsis moricola* nov. sp. G. Del. Bull. Soc. Myc. France, XIX, 342–346, 1903.
8. FOËX, M. E.: I. Les Conidiophores des Erysiphacées. (note préliminaire). II. De la présence deux sortes de conidiophore chez *Oidiopsis taurica* Lév. III. *Oidium alphitoides* GRIFFON et MAUBLANC. (Oidium des Chénes). Ann. Ecol. Nat. Agr. Montpellier, XI, 246–262, 1911.
9. ————: Les "Fibrincörper" de ZOPF et leurs relations avec les corpuscules métachromatiques. Compt. Rend. Hebd. Séan. Acad. Scien. CLV, 2, 661–662, 1912.
10. ————: Evolution du conidiophore de *Sphaerotheca Humuli*. Bull. Soc. Myc. France, XXIX, 251–252, 1913.
11. ————: Notes sur quelques Erysiphacées. Bull. Soc. Myc. France, XLI, 417–438, 1925.
12. HARPER, R. A.: Die Entwicklung des Peritheciums bei *Sphaerotheca Castagnei*. Ber. Deutsch. Bot. Gesell. XIII, 475–481, 1895.
13. ————: Über das Verhalten der Kerne bei der Fruchtentwicklung einiger Ascomyceten. Jahrb. Wiss. Bot. XXIX, 655–685, 1896.
14. ————: Sexual reproduction and the organization of the nucleus in certain mildews. Carnegie Inst. Washington, Public. XXXVII, 1–104, 1905.
15. HART, HELEN: Morphologic and Physiologic studies on Stem-rust resistance in cereals. U. S. Depart. Agr. Wash. D. C. Tech. Bull. no. 266, 1–75, 1931.
16. HOMMA, Y.: On the "Fibrosin-body" of Erysiphaceae. Trans. Sapporo, Nat. Hist. Soc. X, 47–61, 1928.
17. ————: Homothallism in *Sphaerotheca fuliginea* (SCHLECHT.) POLLACCI. Proc. Imp. Acad. IX, 186–187, 1933.

18. HOMMA, Y.: *A life-cycle of Sphaerotheca fuliginea* (SCHLECHT.) POLLACCI parasitic on *Taraxacum ceratophorum* DC. Trans. Sapporo, Nat. Hist. Soc. XIII, 173–178, 1934.
19. HURD, ANNIE MAY: Hydrogen-ion concentration and varietal resistance of wheat to stem-rust and other disease. (*Erysiphe graminis.*) Jour. Agr. Res. XXIII, 373–386, 1923.
20. ————: The course of acidity changes during the growth period of wheat with special reference to stem-rust resistance. Jour. Agr. Res. XXVII, 725–735, 1924.
21. LAIBACH, R.: Über die Bedingungen der Perithezienbildung bei den Erysipheen. Jahrb. Wiss. Bot. LXXII, 100–136, 1930.
22. MAINS, E. B.: Host specialization of *Erysiphe graminis-tritici.* Proc. Nat. Acad. Sci. XIX, 1, 49–53, 1933. (App. Myc. XII, 6, 362, 1933).
23. MARCHAL, E.: De la spécialisation du parasitisme chez l'*Erysiphe graminis.* C. R. H. Acad. Paris, CXXXV, 210, 1902.
24. NEGER, E. W.: Beiträge zur Biologie der Erysipheen. II. Flora, XC, 221–271, 1902.
25. PALLA, E.: Über die Gattung Phyllactinia. Ber. Deutsch. Bot. Gesell. XVII, 64–72, 1899.
26. PERCIVAL, J.: The wheat plant. 1921.
27. REED, G. M.: Infection experiment with the powdery mildew of wheat. Phytopath. II, 81–87, 1912.
28. ————: The mildew of the cereals. Bull. Torr. Bot. Club, XXXVI, 353–398, 1909.
29. ————: Influence of light on infection of certain hosts powdery mildew. Science, XXXIX, 294–295, 1914.
30. ————: The powdery mildew of Avena and Triticum. Miss. Agr. Exp. Stat. Res. Bull. XXIII, 1–19, 1916.
31. ————: Physiological specialization of parasitic fungi Brookl. Bot. Gard. Mem. I, 380–387, 1918.
32. SALMON, E. S.: Monograph of the Erysiphaceae. Mem. Torr. Bot. Club, IX, 1900.
33. ————: On the specialization of parasitism in the Erysiphaceae. Beih. Bot. Centralb. XIV, 261–315, 1903.
34. ————: On *Erysiphe graminis* DC. and its adaptive parasitism within the genus Bromus. Ann. Myc. II, 255–266, 1904.
35. ————: On the stages of development reached by certain biologic forms of Erysiphaceae in cases of non infection. New Phytol. IV, 217–221, 1905.
36. ————: On the variation shown by the conidial stage of *Phyllactinia corylea* (PERS.) KARST. Ann. Myc. III, 493–503, 1905.
37. SANDS, M. C.: Nuclear structure and spore formation in *Microsphaera Alni.* Trans. Wis. Acad. Sci. XV, 733–752, 1907.
38. SAWADA, K.: On the systematic investigation of Phyllactinia in Formosa. Depart. Agr. Govern. Res. Inst. Formosa, Japan, XLIX, 1–91, 1930.
39. SMALL, J.: The Hydroion concentration of plant tissues. Protoplasma, I, 324–333, 1926.

40. SMALL, J.: Hydrogen-ion concentration in plant cells and tissues. 1929.
41. SMITH, G.: The haustoria of the Erysipheae. Bot. Gaz. XXIX, 153–184, 1900.
42. STAKMAN, E. C. & LEVINE, M. N.: The determination of biologic forms of *Puccinia Graminis* on Triticum spp. Minn. Agr. Exp. Stat. Tech. Bull. VIII, 3–10, 1922.
43. VAVILOV, N. I.: Beiträge zur Frage über die verschiedene Widerstandsfähigkeit der Getreide gegen parasitische Pilze. Arb. Versuch. für Pflanzenz. Moskauer Landw. Inst. I, 1–110, 1913.
44. ———: Immunity of fungous diseases as a physiological test in genetics and systematics, exemplified in cereals. Jour. Genet. IV, 50–64, 1914.
45. ———: Immunity of plants to infectious diseases. Ann. Acad. Agr. Petrovskoé, no. 1–4, 1–239, 1918.
46. WENTZEL, ERNA A.: Morphological studies of *Erysiphe aggregata* on *Alnus incana*. Trans. Wis. Acad. Sci. Arts and Lett. XXVI, 241–252, 1931.
47. WINGE, Ö.: Encore le *Sphaerotheca Castagnei*. Bull. Soc. Myc. France, XXVII, 211–218, 1911.
48. ZOPF, W.: Über einen neuen Inhaltkörper in pflanzlichen Zellen. Ber. Deutsch. Bot. Gesell. V, 275–280, 1887.

Systematic Part

49. ARNAUD, G.: Etude sur les Champignons parasites. 4 Tribu des Erysiphées TULASNE. Ann. d. Epiph. VII, 82–108, 1921.
50. BERKELEY, M. J. & CURTIS, M. A.: Characters of new fungi, collected in the North Pacific Exploring Expedition by CHARLES WRIGHT. Proc. Amer. Acad. IV, 14, 130, 1858.
51. ———: Notice of North American fungi. Grev. IV, 160, 1876.
52. BLUMER, S.: Die Perithecien des Eichen-Mehltaues (*Microsphaera alphitoides* GRIFF. & MAUBL.) Mitt. Naturforsch. Gesellsch. Bern, 1924, 44–46, 1925. (App. Myc. V, 65, 1926.)
53. BURRILL, T. J. & EARLE, F. S.: Parasitic fungi of Illinois, II, Bull. Ill. Stat. Lab. Nat. Hist. II, 387–432, 1887.
54. COOKE, M. C.: Handb. of British fungi. II. 645–652, 1871.
55. COOKE, M. C. & PECK, C. H.: The Erysiphei of the United States. Jour. Bot. I, 11–14, 1872.
56. ———: Supplementary notes on the Erysiphei of the United States. Jour. Bot. I, 170–172, 1872.
57. CORDA, A. C. I.: Icones Fungorum, II, 28, 1838; V. 29–30, and 50–51, 1842.
58. DE CANDOLLE, A. P.: Flora Francaise, II, 272–275, 1805, and VI, 104–109, 1815.
59. DOIDGE, E. M.: Some notes on the South African Erysiphaceae. Royal Soc. South Africa, V, 237–245, 1915.
60. ELLIS, J. B. & MARTIN, G.: New Florida fungi. Jour. Myc. I, 101, 1885.

61. ELLIS, J. B. & EVERHART, B. M.: New species of fungi from various localities. Jour. Myc. IV, 58, 1888.
62. ———: North American Pyrenomycetes. 2–30, 1892.
63. ELLIS, J. B. & LANGLOIS, A. B.: New species of Louisiana fungi. Jour. Myc. VI, 35–37, 1890.
64. ENGLER, P.: Die natürlichen Pflanzen-Familien, I, 328–333, and 338, 1879.
65. FOËX, M. E.: Note sur *Oidiopsis taurica* (LÉV.) SALM. Ann. d. l'Ecole nation. d'Agr. de Montp. VIII, 176–184, 1909.
66. FRIES, E.: Systema Mycologicum. III, 234–247, and 427–433, 1829.
67. FUCKEL, L.: Symbolae Mycologicae. 76–86, and 357–358, 1869–1870.
68. GERARD, W. R.: New fungi. V. Bull. Torr. Bot. Club, VI, 31, 1875.
69. GRIFFITHS, D.: Some Northwestern Erysiphaceae. Bull. Torr. Bot. Club, XXVI, 138–144, 1899.
70. GRIFFON, M. E. & MAUBLANC, A: Nouvelles recherches sur la pourriture du coeur de la Betterave. Bull. Soc. Myc. France, XXVI, 126–131, 1910.
71. ———: Les Microsphaera des Chenes. Bull. Soc. Myc. France, XXVIII, 88–104, 1912.
72. GROUT, A. J.: A little-known mildew of apple. Bull. Torr. Bot. Club, XXVI, 373–375, 1899.
73. HARA, K.: New powdery mildew parasitic on trees. Jour. Forest. Assoc. Japan, CCCXCII, 61–64, 1915.
74. ———: Parasitic fungi in Shizuoka. Agr. Report, Shizuoka, CCLXXXII, 29–30, 1921.
75. ———: Dendropathology. 4–31, 1923.
76. ———: Fungus list of east Asia. Agr. Report, Shizuoka, CCCLXIV, 4–10, 1928.
77. HENNINGS, P.: Fungi japonici. I. Engl. Bot. Jahrb. XXVIII, 271–272, 1901.
78. ———: Fungi japonici. II. Engl. Bot. Jahrb. XXIX, 147–150, 1901.
79. ———: Fungi japonici. III. Engl. Bot. Jahrb. XXXII, 41–42, 1903.
80. ———: Fungi japonici. V. Engl. Bot. Jahrb. XXXIV, 600, 1905.
81. HOMMA, Y.: On the goose-berry mildew. Hortc. XIX, 4–5, 1927.
82. ———: On the powdery mildew of flax. Bot. Mag. Tokyo, XLII, 331–334, 1928.
83. ———: A statistical study on the biological forms of *Erysiphe graminis* DC. Trans. Sapporo, Nat. Hist. Soc. X, 157–161, 1929.
84. ———: Notes on the Erysiphaceae of Manchuria. Trans. Sapporo Nat. Hist. Soc. XI, 169–174, 1930.
85. HOWE, E. C.: New fungi. Bull. Torr. Bot. Club, V, 3–4, and 43, 1874.
86. IDETA, A.: Practical Phytopathology. 156–165, and 170, 1901.
87. ———: Japanese Phytopathology. 195–217, and 226, 1909–1911.
88. ———: Japanese Phytopathology. (Suppl. I) 198–223, 1923.
89. ITO, S.: On Typhulochaeta, a new genus of Erysiphaceae. Bot. Mag. Tokyo, XXIX, 15–22, 1915.

90. Ito, S.: A new genus of Erysiphaceae. Trans. Sapporo Nat. Hist. Soc. V, 198–203, 1915.

91. Jaap, O.: Ein kleiner beitrag zur Pilzflora der Vogesen. Ann. Myc. IX, 333, 1911.

92. Jaczewski, A.: Monographie des Erysiphées de la Suisse. Bull. l'Herb. Boiss. IV, 722–755, 1896.

93. Jørstad, I.: The Erysiphaceae of Norway. 1–116, 1925.

94. Karsten, P. A.: Revisio Monographica atque Synopsis Ascomycetum in Fennia hucusque detectorum. Act. Soc. Faum. Pl. Fenn. Helsingfors, II, 91–95, 1885.

95. Kickx, J. J.: Flore cryptogamique des Flandres. I, 374–384, and II, 297–298, 1867.

96. Klika, J.: Monografie českých padli. Příspěvek k Mykologickému a fytopathologickemu výzkumu Čech. Spisy masar. Akad. Práce, XXIII, 1–80, 1924.

97. Kusano, S.: The haustoria in Erysiphaceae. Bot. Mag. Tokyo, XIV, 173, 1901.

98. ————: On the rust fungi in winter of Izu Dist. Bot. Mag. Tokyo, XVI, 201, 1902.

99. ————: The parasitic fungi collected in Chugoku Dist. Bot. Mag. Tokyo, XVI, 203, 1902.

100. Lawrence, W. H.: Notes on the Erysiphaceae of Washington. Jour. Myc. XI, 106–108, 1905.

101. Léveillé, J. H.: Des Espéces qui composent le genre Erysiphé. Ann. Sci. Nat. III, 15, 133–170, 1851.

102. Lind, J.: Danish Fungi. 159–165, 1913.

103. Lindau, G.: Rabenhorst's Kryptogamenflora. VIII, 78–89, 1907; and IX, 724–726, 1910.

104. Link, H. F.: Observations in Ordines plantarum naturales. Dissertatio I, complectens Anandrarum ordines Epiphytas, Mucedines, Gastromycos et Fungos. Magaz. d. Ges. Naturf. Frunde, Berlin, III, 3–24, 1809.

105. ————: Species Hyphomycetum et Gymnomycetum. Spec. Pl. VI, 1, 121–162, 1824.

106. Linneus, C.: Species Plantarum. II, 1186, 1753.

107. Magnus, P.: Die Erysipheen Tirols. Ber. natur.-mediz. Ver. in Inn. XXIV, 3–25, 1898.

108. ————: Ein bei Berlin auf *Caragana arborescens* Lam. epidemisch auftretender Mehlthau. Ber. Deutsch. Bot. Gesell. XVII, 148, 1899.

109. ————: Einige geschuldete mykologische Mitteilungen. Hedw. XLIV, 16–18, 1905.

110. Malbranche, M. A.: Plantes rares, litigieuses on nouvelles, observées récemment en normandie. Bull. Soc. Myc. France, IV, xxxii, 1888.

111. Matsumura, N.: Index of Japanese Plants. 1904.

112. Mérat, F. V.: Nouvelle Flora des environs de Paris. 23, and 74–76, 1837.

113. ————: Synopsis de la Nouvelle Flora des environs de Paris. 10, and 83–84, 1837.

114. MIURA, M.: Flora of Manchuria and East Mongolia. III. Cryptogams, Fungi. Publ. South Manch. Rwy. Co. XXVII, 113–141, 1928.

115. MIYAKE, I.: *Über einige Pilz-krankheiten unseres Nutzpflanzen.* Bot. Mag. Tokyo, XXI, 1–6, 1907.

116. ———: Studies in Chinese fungi. Bot. Mag. Tokyo, XXVI, 53–54, 1912.

117. ———: *Studien über chinesischen Pilze.* Bot. Mag. Tokyo, XXVII, 38–40, 1913.

118. ———: Über chinesischen Pilze. Bot. Mag. Tokyo, XXVIII, 38–39, 1914.

119. NAMBU, N.: The parasitic fungi collected in the vicinity of Tokyo. Bot. Mag. Tokyo, XVIII, 3, 1904.

120. ———: A list of parasitic fungi. Bot. Mag. Tokyo, XX, 252, 1906.

121. NEES, V. ESENBECK, C. G.: Das system der Pilze und Schwämme. 148, 1914.

122. NEGER, F. W.: Kryptogamenflora der Mark Brandenburg. VII, 96–135, 1905.

123. ———: Der Eichenmehltau (*Microsphaera Alni* (WALLR.), var. *quercina*). Naturw. Zeitschr. Forst. u. Landw. XIII, 1–26, 1915.

124. NISHIDA, T.: *The list of fungi collected in Prov. Etchu. Bot. Mag. Tokyo,* XVI, 274, 1902.

125. OUDEMANS, C. A. J. A.: Révision des Champignons des Pays-Bas, 77–99, 1897.

126. PAMMEL, L. H.: Some mildews of Illinois. Jour. Myc. IV, 36–38, 1888.

127. PRILLIEUX, E.: Maladies des Plantes Agricoles. II, 8–38, 1897.

128. PATOUILLARD, N. & HARIOT, P.: Enumeration des champignons récoltés par M. A. CHEVALIER au Sénégal et dans le Soudan occiental. Jour. de Bot. XIV, 234–246, 1900.

129. POLLACCI, G.: Monografia delle Erysiphaceae Italiane. Att. R. Istit. Bot. dell'Univ. d. Pavia, II, IX, 1–30, 1905.

130. QUÉLET, L.: Les Champinion du Jura et des Vosges. Champ. Jur. Vosg. 531–535, 1875.

131. RABENHORST, L.: Deutschlands Kryptogamen-Flora, I, 230–237, 1844.

132. ———: *Oidium Chrysanthemi* n. sp. Hedw. I, 19–21, 1862.

133. RANOJEVIC, N.: Beitrage zur Pilzflora Serbiens. Hedw. XLI, 102, 1902.

134. ———: *Zwiter Beitrage zur Pilzflora Serbiens.* Ann. Myc. VIII, 347–402, 1910.

135. REHM, H.: Ascomyceten. Fasc. XVI. Hedw. XXIV, 66–72, 1885.

136. ———: Ascomycetes exs. Fasc. LV. Ann. Myc. XII, 170, 1914.

137. SACCARDO, P. A.: Fungi Gallici. Michelia, II, 50, 1880.

138. ———: Syll. Fung. I, 1–23, 1883; IV, 40–47, 1886; IX, 364–371, 1891; X, 520–521, 1892; XI, 252–253, 1895; XIV, 462, and 1041–1042, 1899; XVI, 398–405, and 1025–1026, 1902; XVII, 524–527, 1905; XVIII, 505–506, 1906; XXII, 19–25, 1913; and XXIV, 223–226, 1926.

139. ———: Notae Mycologicae. Ann. Myc. VIII, 339, and 342–343, 1910.

140. ———: Notae Mycologicae. Ann. Myc. IX, 249, 1911.

141. SALMON, E. S.: *A new species of Uncinula from Japan.* Jour. Bot. XXXVII, 426–427, 1900.

142. SALMON, E. S.: Erysiphaceae of Japan. Bull. Torr. Bot. Club, XXVIII, 437–450, 1900.
143. ————: Supplemental notes on the Erysiphaceae. Bull. Torr. Bot. Club, XXIX, 1–22, 83–100, 181–210, 302–316, and 647–649, 1902.
144. ————: On the identify of Ovulariopsis PATOUILLARD and HARIOT with the conidial stage of Phyllactinia. Ann. Myc. II, 438–443, 1904.
145. ————: Erysiphaceae of Japan. II. Ann. Myc. III, 241–255, 1905.
146. ————: Preliminary note on an endophytic species of the Erysiphaceae. Ann. Myc. III, 82–83, 1905.
147. ————: On *Oidiopsis taurica* (LÉV.) and endophytic member of the Erysiphaceae. Ann. Bot. XX, 187–200, 1906.
148. ————: Erysiphaceae of Japan. III. Ann. Myc. VI, 1–16, 1908.
149. SAWADA, K.: The Classification of the Erysiphaceae based on the conidial stages. Agr. Exp. Stat. Formosa, Bull. IX, 1–102, 1914.
150. ————: The genus Cystotheca is to be retained or not. Trans. Sapporo Nat. Hist. Soc. V, 204–209, 1915.
151. ————: A list of Formosa fungi. Trans. Formosa Nat. Hist. Soc. VI, 27–35, 1916.
152. ————: Descriptive catalogue of the Formosan fungi, I, Agr. Exp. Stat. Formosa, Spec. Bull. XIX, 139–193, 1919.
153. ————: On the systematic investigation of the Formosan Erysiphaceae in Oidium stages. Depart. Agr. Governm. Res. Inst. Formosa, Japan, XXIV, 1–55, 1927.
154. ————: Descriptive catalogue of the Formosan fungi, VI. Depart. Agr. Governm. Res. Inst. Formosa, Japan, LXI, 28–38, and 77–89, 1933.
155. SCALIA, G.: Di una nuiya malattia dell'*Asclepias curassavica* SPR. L'Agric. Calabro-Siculo, XXVII, 393–397, 1902.
156. SCHRÖTER, J.: Die Pilze Schlesiens. *Cohn's* Krypt. Fl. Schlesien, III, 2, 229–247, 1893.
157. SHIRAI, M.: The disease of the Koshu-grape. Bot. Mag. Tokyo, V. 341, 1891.
158. ————: On the parasitic disease of crops in Saitama Dist. Bot. Mag. Tokyo, VI, 330, 1892.
159. ————: The crop-fungi collected in Shikoku. Bot. Mag. Tokyo, XI, 168, 1897.
160. ————: A List of Japanese Fungi. 1905.
161. SHIRAI, M. & MIYAKE, I.: A List of Japanese Fungi. 1917.
162. SHIRAI, M. & HARA, K.: A List of Japanese Fungi. 1927.
163. ŠKOBIĆ, V.: Erysiphaceae Croatiae. Glasnik za Šumske Pokuse, I. 52–67, 1926.
164. STEVENS, F. L.: List of New York fungi. Jour. Myc. XIII, 68, 1907.
165. SYDOW, H. & P.: Fungi novi japonici. Mem. Herb. Boiss. IV, 4, 1900.
166. ————: Micromycetes japonici. Ann. Myc. VII, 170, 1909.
167. ————: Ein Beitrage zur Kenntnis der parasitischen Pilzflora des nördlichen Japan. Ann. Myc. XI, 113–115, 1913.
168. ————: Zweiter Beitrage zur Kenntnis der parasitischen Pilzflora des nördlichen Japan. Ann. Myc. XII, 160–161, 1914.

169. TAI, F. L. & WEI, C. T.: Notes on Chinese fungi, II. (Erysiphaceae). Sinensia III. 93–130, 1932.
170. TANAKA, E.: On the fungi. Bot. Mag. Tokyo, I, 38, 1887.
171. ————: On the collection of the fungi. Bot. Mag. Tokyo, IV, 298, 1890.
172. TANAKA, C.: New Japanese fungi notes and translations VI. Myc. XI, 80–82, 1919.
173. THEISSEN, F. & SYDOW, H.: Synoptische Tafeln. Ann. Myc. XV, 453–457, 1917.
174. TOGASHI, K.: Fungi collected in the Islands of Rishiri and Rebun, Hokkaido. Jap. Jour. Bot. II, 78–79, 1924.
175. TOGASHI, K. & HIRATSUKA, N.: On the parasitic fungi collected in Cape-Noshappu. Trans. Sapporo Nat. Hist. Soc. XVI, 74, 1924.
176. TRACY, S. M. & GALLOWAY, B. T.: Notes on Western Erysipheae and Peronosporeae. Jour. Myc. IV, 33–36, 1888.
177. TULASNE, L. R. & C.: Selecta Fungorum Carpologia I, 191–216, 1861.
178. v. HÖHNEL, F.: Beitrage zur Mykologie. 1. Über die Berechtigung der Gattungen Cystotheca und Thyrococcum. Zeits. für Gärungs-Physiologie, I, 45–48, 1912.
179. WALLROTH, F. W.: Naturgeschichte des *Mucor Erysiphe* L. Berl. Ges. Nat. Freunde, Verhand, I, 6–45, 1819.
180. WINTER, G.: Die Pilze. Rabenh. Krypt. Fl. Deuts. Oest. und Schweiz. II, 22–42, 1884.
181. YOSHINAGA, T.: On some fungi from Tosa. I. Bot. Mag. Tokyo, XV, 94, 1901.
182. ————: On some fungi from Tosa. III. Bot. Mag. Tokyo, XVIII, 31, and 32, 1904.
183. YOSHINO, K.: List of fungi from Prov. Higo. Bot. Mag. Tokyo, XIX, 205–207, 1905.

Explanation of Plates

In the explanation of plates unless otherwise stated, all figures are magnified × 230.

Plate IV, A

Formation of conidia

Fig. 1. *Sphaerotheca fuliginea on Taraxacum ceratophorum.*
a. Young conidiophore. b. Spore-mother cell on conidiophore.
c–e. Chain of spores on spore-mother cell.

Fig. 2. *Podosphaera tridactyla* on *Prunus triflora.*
Chain of spores on spore-mother cell; two nuclei in conidiophore.

Fig. 3. *Erysiphe Cichoracearum* on *Plantago major* var. *asiatica.*
a. Young conidiophore. b. Spore-mother cell on conidiophore.
c–e. Chain of spores on spore-mother cell.

Fig. 4. *Erysiphe graminis* on *Triticum vulgare.*
a–c. Young conidiophore.
d. Spore-mother cell on conidiophore.
e–j. Chain of spores on spore-mother cell.

Fig. 5. *Erysiphe Polygoni* on *Polygonum aviculare.*
a–c. Young conidiophore.
d. Spore-mother cell on conidiophore.
e–h. Chain of spores on spore-mother cell.

Fig. 6. *Uncinula Actinidiae* on *Actinidia arguta.*
a. Young conidiophore.
b. Spore-mother cell on conidiophore.
c. Young conidium on spore-mother cell.

Fig. 7. *Microsphaera alphitoides* on *Quercus crispula.*
a–b. Young conidiopohre.
c. Spore-mother cell on conidiophore.
d–e. Young conidium on spore-mother cell.

Fig. 8. *Phyllactinia imperialis* on *Paulownia tomentosa.*
a–b. Young conidium on spore-mother cell.
c–d. Chain of spores on spore-mother cell.

Plate IV, B

Structure of perithecia, × 250.

Fig. 1. *Cystotheca Wrightii* on *Quercus glauca.*
Fig. 2. *Cystotheca lanestris* on *Quercus serrata.*
Fig. 3. *Sphaerotheca fuliginea* on *Taraxacum ceratophorum.*
Fig. 4. *Podosphaera tridactyla* on *Prunus triflora.*
Fig. 5. *Typhulochaeta japonica* on *Quercus serrata.*
Fig. 6. *Uncinulopsis Shiraiana* on *Celtis sinensis*

Fig. 7. *Erysiphe Cichoracearum* on *Plantago major* var. *asiatica*.
Fig. 8. *Uncinula Actinidiae* on *Actinidia arguta*.
Fig. 9. *Microsphaera Alni* on *Picrasma quassioides*.
a. Perithecium.
b. Young appendage.
Fig. 10. *Sawadaea Tulasnei* on *Acer pictum*.
Fig. 11. *Phyllactinia imperialis* on *Paulownia tomentosa*.
a. Perithecium, × 130.
b. Penicillate cell.

Plate V

Formation of perithecia in *Sphaerotheca fuliginea* on *Taraxacum ceratophorum*

Fig. 1–2. Male and female branches, × 720.
Fig. 3–4. Antheridium and ascogonium, × 720.
Fig. 5. Antheridial and ascogonial hyphae coiled each other, × 510.
Fig. 6. Male and female nuclei in ascogonium, × 720.
Fig. 7. Young ascus, including two nuclei, × 720.
Fig. 8. Young ascus, including a large nucleus, × 720.

Plata VI, A

Formation of perithecia in *Sphaerotheca fuliginea* on *Taraxacum ceratophorum*

Fig. 1. Male and female branches, × 340.
Fig. 2–3. Antheridium and ascogonium, using the living sample, Fig. 2, × 340, fig. 3, × 300.
Fig. 4–5. Primary perithecial wall cells from stalk-cell of ascogonium, × 340.
Fig. 6–7. Male and female nuclei in ascogonium, × 340.
Fig. 8. Primary wall closed at upper part of ascogonium, using the living sample, × 300.
Fig. 9. Conjugated nucleus, × 340.
Fig. 10. Two nuclei formed by division, × 340.
Fig. 11. Two cells from ascogonium, × 340.
Fig. 12–13. Three cells from ascogonium, × 340.
Fig. 14. Young ascus including a large nucleus and binucleated perithecial wall cells, × 340.
Fig. 15. Two nuclei in ascus, × 340.
Fig. 16. Four nuclei in ascus, × 340.
Fig. 17. Outer and inner perithecial walls and young appendage, × 340.

Plate VI, B

Formation of perithecia

Fig. 1. *Cystotheca lanestris* on *Quercus serrata.*
a. Antheridium and ascogonium. b. Primary perithecial wall cells. c. Four cells from ascogonium, × 340.

Fig. 2. *Podosphaera tridactyla* on *Prunus triflora.*
a. Antheridium and ascogonium, using the living sample, × 300. b. Primary wall closed at upper part of ascogonium, using the living sample, × 300. c. Two cells from ascogonium, × 340. d. Four cells from ascogonium, × 340. e. Young ascus, × 340.

Fig. 3. *Erysiphe Cichoracearum* on *Plantago major* var. *asiatica.*
a. Male and female branches, using the living sample, × 300. b. Antheridium and ascogonium, using the living sample, × 300. c. Primary perithecial wall cells from stalk cell of ascogonium, using the living sample, × 300. d. Two nuclei in ascogonium, × 340. e. Two cells from ascogonium, × 340. f. Three cells from ascogonium, × 340. g. Ascogenous hypha in young perithecium, × 340. h. Young ascus from ascogenous hypha, × 340.

Fig. 4. *Uncinula Actinidiae* on *Actinidia arguta.*
a–b. Antheridium and ascogonium, using the living samples, × 300. c. Two cells from ascogonium, × 340. d. Three cells from ascogonium, × 340. e. Three perithecial walls, × 340.

Fig. 5. *Sawadaea Tulasnei* on *Acer pictum,* × 340.
a. Antheridium and ascogonium. b–d. Primary perithecial wall cells from stalk-cell. e. Two cells from ascogonium. f. Four asci.

Fig. 6. *Typhulochaeta japonica* on *Quercus serrata,* × 340.
a–b. Primary perithecial wall cells from stalk-cell. c. Ascogonium enclosed in primary perithecial wall. d. Ascogonium enclosed in two perithecial walls.

Fig. 7. *Microsphaera Alni* on *Picrasma quassioides,* × 340.
a. Antheridium and ascogonium. b. Two nuclei in ascogonium. c. Two cells from ascogonium. d. Three cells from ascogonium; two nuclei in second cell. e. Third perithecial wall cells formed from second wall. f. Fourth or fifth perithecial wall cells formed from third or fourth walls. g. Three young asci.

Plate VI, C

Infection with conidia of *Erysiphe graminis* parasitic on *Triticum vulgare.*

Fig. 1. Conidia after 1 day from inoculation.
Fig. 2. Conidia after 2 days from inoculation.
Fig. 3. Conidia after 3 days from inoculation.
Fig. 4. Conidia after 5 days from inoculation.
Fig. 5. Conidia after 7 days from inoculation.
Figs. 1–5, × 210.

Fig. 6. Penetration tube and incipient haustorium after 4 days from inoculation.
Fig. 7. Incipient haustorium after 5 days from inoculation.
Fig. 8–9. Haustoria after 10 days from inoculation.
6–8, × 340.
Fig. 10. Infection spots on stripped epidermis.
9–10, × 210.

Plate VI, D

Haustoria and inner mycelia.

Fig. 1. *Cystotheca lanestris* on *Quercus serrata*, × 340.
Fig. 2. *Sphaerotheca fuliginea* on *Taraxacum ceratophorum*, × 340.
Fig. 3. *Podosphaera tridactyla* on *Prunus triflora*, × 340.
Fig. 4. *Erysiphe Cichoracearum* on *Plantago major* var. *asiatica*, × 340.
Fig. 5. *Sawadaea Tulasnei* on *Acer pictum*, × 340.
Fig. 6. *Typhulochaeta japonica* on *Quercus serrata*, × 340.
Fig. 7. *Uncinula Actinidiae* on *Actinidia arguta*, × 340.
Fig. 8. *Microsphaera Alni* on *Picrasma quassioides*, × 340.
Fig. 9. *Uncinulopsis Shiraiana* on *Celtis sinensis*, × 340.
Fig. 10. *Phyllactinia imperialis* on *Paulownia tomentosa*, × 340.
Fig. 11. *Leveillula taurica* on *Capsicum annuum*, × 250.

Plate VII

Fig. 1. *Cystotheca Wrightii* on *Quercus glauca*.
a. Perithecia, × 85. b. Inner wall cells of perithecium. c. Hairs. d. Ascus. e. Conidia.
Fig. 2. *Cystotheca Wrightii* on *Pasania cuspidata*.
Conidia.
Fig. 3. *Cystotheca lanestris* on *Quercus major*.
a. Perithecium, × 85. b. Outer wall cells of perithecium. c. Inner wall cells of perithecium. d. Hairs. e. Ascus. f. Ascospores. g. Conidia.
Fig. 4. *Sphaerotheca Humuli* on *Agrimonia pilosa*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Ascus. d. Ascospores. e. Conidia.
Fig. 5. *Sphaerotheca Humuli* on *Aruncus sylvester* var. *vulgaris*.
Ascus and ascospores.
Fig. 6. *Sphaerotheca Humuli* on *Spiraea Thunbergii*.
a. Perithecium, × 40. b. Appendages. c. Ascus.
Fig. 7. *Sphaerotheca Humuli* on *Veronica sibirica*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Ascus. d. Two asci included in a perithecium.

Fig. 8. *Sphaerotheca Epilobii* on *Epilobium Behringianum.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendage. d. Ascus and ascospores.

Fig. 9. *Sphaerotheca Epilobii* on *Epilobium montanum.*
Conidia.

Fig. 10. *Sphaerotheca fuliginea* on *Taraxacum ceratophorum.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Ascus and ascospores. d. Conidia.

Fig. 11. *Sphaerotheca fuliginea* on *Cucurbita moschata* var. *Toonas.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendage. d. Ascus. e. Conidia.

Fig. 12. *Sphaerotheca fuliginea* on *Adenocaulon bicolor.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Ascus and ascospores. d. Conidia.

Fig. 13. *Sphaerotheca fuliginea* on *Phtheirospermum japonicum.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Ascus and ascospores.

Fig. 14. *Sphaerotheca fuliginea* on *Bidens pilosa.*
Branching appendage.

Fig. 15. *Sphaerotheca fuliginea* on *Siegesbechia orientalis.*
Branching appendage.

Fig. 16. *Sphaerotheca Mors-Uvae* on *Ribes grossularia.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Ascus and ascospores. d. Conidia.

Fig. 17. *Sphaerotheca japonica* on *Stephanandra incisa.*
Perithecium, × 40.

Fig. 18. *Sphaerotheca pannosa* on *Rosa multiflora.*
Conidia.

Fig. 19. *Podosphaera leucotricha* on *Malus baccata* var. *mandschurica.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Ascus and ascospores. d. Conidia.

Fig. 20. *Podosphaera tridactyla* on *Prunus triflora.*
a. Perithecium, × 100. b. Wall cells of perithecium. c. Ascus and ascospores. d. Conidia.

Fig. 21. *Podosphaera spiralis* on *Ulmus japonica.*
a. Perithecium, × 100. b. Wall cells of perithecium. c. Ascus and ascospores.

Fig. 22. *Podosphaera Oxyacanthae* on *Spiraea salicifolia.*
a. Perithecium, × 100. b. Wall cells of perithecium. c. Ascus and ascospores.

Fig. 23. *Erysiphe Pisi* on *Desmodium podocarpum.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Asci and ascospores.

Fig. 24. *Erysiphe Pisi* on *Pisum sativum.*
Conidia and conidiophore.

Plate VIII

Fig. 1. *Erysiphe Pisi* on *Falcata japonica*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Ascus and ascospores. d. Conidia.

Fig. 2. *Erysiphe Pisi* on *Alnus firma*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Ascus.

Fig. 3. *Erysiphe Heraclei on Seseli Libanotis*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendages. d. Ascus and ascospores.

Fig. 4. *Erysiphe Heraclei* on *Quercus glauca*.
a. Perithecium, × 40. b. Ascus and ascospores.

Fig. 5. *Erysiphe Heraclei* on *Torilis Anthriscus*.
Conidia and conidiophores.

Fig. 6. *Erysiphe Polygoni* on *Polygonum aviculare*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Ascus and ascospores. d. Conidia and conidiophores.

Fig. 7. *Erysiphe Polygoni* on *Elsholtzia Patrini*.
a. Perithecium, × 40. b. Ascus. c. Conidia and conidiophores. d. Haustorium.

Fig. 8. *Erysiphe Polygoni* on *Sedum Telephium* var. *purpureum*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Ascus and ascospores. d. Conidia.

Fig. 9. *Erysiphe Aquilegiae* on *Paeonia japonica*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Ascus and ascospores. d. Appendages.

Fig. 10. *Erysiphe Aquilegiae* on *Aquilegia flabellata* var. *pumila*.
Conidia.

Fig. 11. *Erysiphe Aquilegiae* on *Caltha palustris* var. *gigas*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Asci and ascospores.

Fig. 12. *Erysiphe graminis* on *Hordeum sativum*.
a. Perithecium, ×40. b. Wall cells of perithecium. c. Ascus and ascospores. d. Conidia and conidiophore.

Fig. 13. *Erysiphe Cichoracearum on Artemisia vulgaris* var. *kamtschatica*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Asci and ascospores. d. Conidia and conidiophore.

Fig. 14. *Erysiphe Cichoracearum* on *Plantago major* var. *asiatica*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Ascus and ascospores. *d. Conidia.*

Fig. 15. *Erysiphe Galeopsidis* on *Lamium album* var. *barbatum*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Asci. d. Conidia and conidiophore.

Fig. 16. *Uncinula Clintonii* on *Celtis sinensis*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendages. d. Asci and ascospores.

Fig. 17. *Uncinula Clintonii on Tilia japonica.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendage. d. Asci and ascospores.

Fig. 18. *Uncinula Clintonii* on *Aphananthe aspera.*
a. Perithecium, × 100. b. Asci and ascospores.

Fig. 19. *Uncinula Zelkowae* on *Zelkowa serrata.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendages. d. Ascus and ascospores. e. Conidia.

Fig. 20. *Uncinula clandestina* on *Ulmus japonica.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendage. d. Asci and ascospores.

Fig. 21. *Uncinula Delavayi* on *Cedrela sinensis.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendages. d. Ascus and ascospores.

Fig. 22. *Uncinula bifurcata* on *Quercus serrata.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendages. d. Ascus and ascospores.

Fig. 23. *Uncinula australiana* on *Lagerstroemia indica.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendage. d. Conidia.

Fig. 24. *Uncinula Sengokui* on *Celastrus articulata.*
a. Appendages. b. Ascus and ascospores. c. Conidia.

Plate IX

Fig. 1. *Uncinula Salmoni* on *Fraxinus mandschurica* var. *japonica.*
a. Wall cells of perithecium. b. Appendages. c. Ascus and ascospores.

Fig. 2. *Uncinula Picrasmae* on *Picrasma quassioides.*
a. Wall cells of perithecium. b. Appendages. c. Ascus and ascospores.

Fig. 3. *Uncinula Actinidiae* on *Actinidia polygama.*
a. Appendages. b. Ascus and ascospores. c. Conidia.

Fig. 4. *Uncinula verniciferae* on *Rhus vernicifera.*
a. Wall cells of perithecium. b. Appendages. c. Asci and ascospores.

Fig. 5. *Uncinula Salicis* on *Salix Hultenii* var. *angustifolia.*
a. Perithecium, × 40. b. Appendages. c. Conidia and conidiophore.

Fig. 6. *Uncinula Salicis* on *Salix gracilistyla.*
a. Perithecium, × 40. b. Appendages.

Fig. 7. *Uncinula Salicis* on *Populus Sieboldii.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendages. d. Ascus.

Fig. 8. *Uncinula simulans* on *Rosa multiflora.*
a. Appendages. b. Asci.

Fig. 9. *Uncinula curvispore* on *Fagus japonica.*
a. Wall cells of perithecium. b. Appendages. c. Ascus.

Fig. 10. *Uncinula septata* on *Quercus serrata.*
a. Wall cells of perithecium. b. Appendages. c. Ascus.

Fig. 11. *Uncinula geniculata* on *Styrax Obassia.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendages d. Ascus and ascospores.

Fig. 12. *Uncinula Betulae* on *Betula Tauschii.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendages d. Ascus and ascospores.

Fig. 13. *Uncinula carpinicola* on *Carpinus laxiflora.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendages d. Asci and ascospores.

Fig. 14. *Uncinula Fraxini* on *Fraxinus longicuspis.*
a. Wall cells of perithecium. b. Appendages. c. Asci and ascospores

Fig. 15. *Uncinula Miyabei* on *Alnus japonica.*
a. Perithecium, × 100. b. Wall cells of perithecium. c. Ascus and ascospores. d. Conidia.

Fig. 16. *Uncinula Miyabei* on *Alnus hirsuta* var. *sibirica.*
Appendages.

Fig. 17. *Uncinula Mori* on *Morus bombycis.*
a. Perithecium, × 100. b. Wall cells of perithecium. c. Appendages d. Asci and ascospores.

Fig. 18. *Uncinula Nishidana* on *Sterculia platanifolia.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendages d. Ascus and ascospores.

Fig. 19. *Typhulochaeta japonica* on *Quercus serrata.*
a. Perithecium, × 40. b. Wall cells of peritbecium. c. Appendages. d. Asci and ascospores.

Fig. 20. *Sawadaea Aceris* on *Acer cissifolium.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendages. d. Asci and ascospores.

Fig. 21. *Sawadaea Tulasnei* on *Acer pictum.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendages d. Asci and ascospores. e. Macro-conidia and conidiophore. f. Micro-conidia and conidiophore.

Fig. 22. *Sawadaea Negundinis* on *Acer Negundo.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendage. d. Asci and ascospores. e. Macro-conidia and conidiophore. f. Micro-conidia and conidiophore.

Plate X

Fig. 1. *Microsphaera Alni* on *Alnus hirsuta.*
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendage. d. Asci and ascospores. e. Conidia and conidiophore.

Fig. 2. *Microsphaera Alni* on *Castanea crenata*.
a. Appendage. b. Ascus and ascospores. c. Conidia and conidiophore.

Fig. 3. *Microsphaera Alni* on *Syringa japonica*.
Appendage.

Fig. 4. *Microsphaera Alni* on *Schizandra chinensis*.
a. Wall cells of perithecium. b. Appendages. c. Ascus and ascospores.

Fig. 5. *Microsphaera Alni* on *Picrasma quassioides*.
a. Wall cells of perithecium. b. Appendages. c. Ascus and ascospores.

Fig. 6. *Microsphaera Alni* on *Cornus controversa*.
a. Wall cells of perithecium. b. Appendages. c. Ascus and ascospores.

Fig. 7. *Microsphaera Alni* on *Lonicera tatarica*.
a. Wall cells of perithecium. b. Appendages. c. Asci and ascospores.

Fig. 8. *Microsphaera calocladophora* on *Quercus rubra*.
a. Wall cells of perithecium. b. Appendages. c. Ascus and ascospores.

Fig. 9. *Microsphaera alphitoides* on *Quercus crispula*.
a. Appendages. b. Ascus and ascospores. c. Conidia and conidiophore.

Fig. 10. *Microsphaera alphitoides* on *Quercus dentata*.
a. Appendage. b. Conidia and conidiophore.

Fig. 11. *Microsphaera alphitoides* on *Quercus serrata*.
a. Wall cells of perithecium. b. Appendages. c. Ascus and ascospores.

Fig. 12. *Microsphaera Ligustri* on *Ligustrum medium*.
a. Wall cells of perithecium. b. Appendages. c. Asci and ascospores.

Fig. 13. *Microsphaera divaricata* on *Symplocos crataegoides*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendages. d. Ascus and ascospores.

Fig. 14. *Microsphaera Coryli* on *Corylus rostrata* var. *mandshurica*.
a. Perithecium, × 40. b. Appendages. c. Ascus and ascospores. d. Conidia.

Fig. 15. *Microsphaera Yamadai* on *Hovenia dulcis*.
a. Appendage. b. Ascus and ascospores.

Fig. 16. *Microsphaera Yamadai* on *Juglans Sieboldiana*.
Appendages.

Fig. 17. *Microsphaera Euphorbiae* on *Securinega flueggeoides*.
a. Perithecium, × 40. b. Appendage. c. Ascus and ascospores.

Fig. 18. *Microsphaera Abeliae* on *Abelia spathulata*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendages. d. Asci and ascospores.

Fig. 19. *Microsphaera pseudo-Lonicerae* on *Cocculus trilobus*.
a. Wall cells of perithecium. b. Appendage. c. Asci and ascospores.

Fig. 20. *Microsphaera Berberidis* on *Berberis vulgaris*.
a. Perithecium, × 100. b. Wall cells of perithecium. c. Appendage. d. Asci and ascospores. e. Conidia.

Fig. 21. *Microsphaera Grossulariae* on *Sambucus racemosa*.
a. Wall cells of perithecium. b. Appendage. c. Asci and ascospores. d. Conidia.

Fig. 22. *Microsphaera diffusa* on *Magnolia obovata*.
a. Wall cells of perithecium. b. Appendages. c. Asci and ascospores. d. Conidia.

Fig. 23. *Microsphaera Russelii* on *Oxalis corniculata*.
Conidia and conidiophore.

Plate XI

Fig. 1. *Microsphaera Bäumleri* on *Vicia Cracca*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendages. d. Asci and ascospores. e. Conidia and conidiophore.

Fig. 2. *Microsphaera Bäumleri* on *Robinia pseudacacia*.
a. Appendages. b. Asci and ascospores.

Fig. 3. *Microsphaera Viciae-unijugae* on *Vicia unijuga*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendages. d. Asci and ascospores. e. Conidia and conidiophore.

Fig. 4. *Uncinulopsis Shiraiana* on *Celtis sinensis*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendages. d. Asci and ascospores. e. Conidia and conidiophores.

Fig. 5. *Phyllactinia corylea* on *Corylus rostrata*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendage. d. Penicillate cell.

Fig. 6. *Phyllactinia corylea* on *Amelanchier japonica*.
Asci and ascospores.

Fig. 7. *Phyllactinia corylea* on *Caesalpinia sepiaria*.
Appendages.

Fig. 8. *Phyllactinia corylea* on *Hamamelis japonica*.
Appendages.

Fig. 9. *Phyllactinia corylea* on *Rhododendron Albrechtii*.
Appendages.

Fig. 10. *Phyllactinia moricola* on *Morus bombycis*.
a. Perithecium, × 40. b. Appendage. c. Asci and ascospores. d. Conidia. e. Penicillate cell.

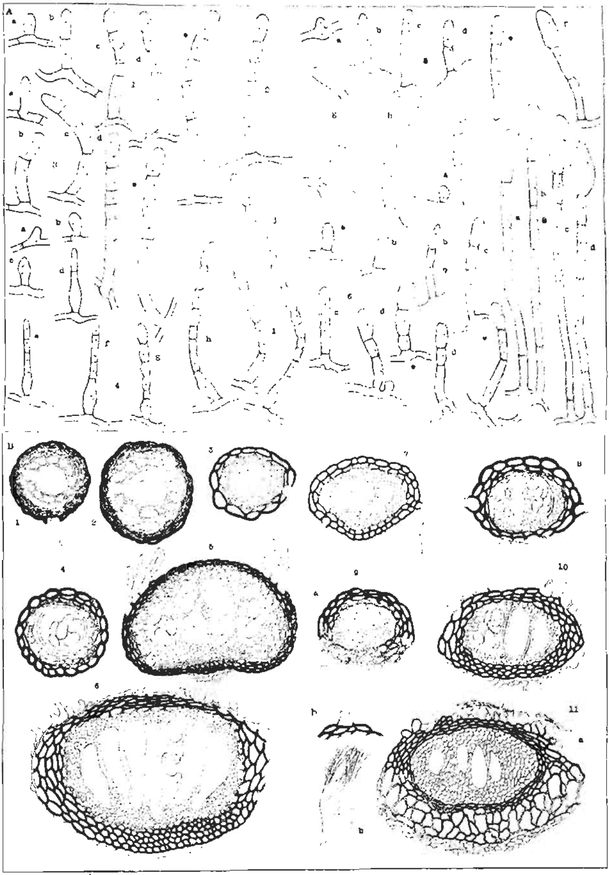
Fig. 11. *Phyllactinia Fraxini* on *Fraxinus mandshurica* var. *japonica*.
a. Perithecium, × 40. b. Wall cells of perithecium. c. Appendage. d. Asci and ascospores.

Fig. 12. *Phyllactinia Fraxini* on *Actinidia arguta*.
a. Perithecium, × 40. b. Appendage. c. Asci and ascospores. d. Conidia and conidiophores. e. Penicillate cells.

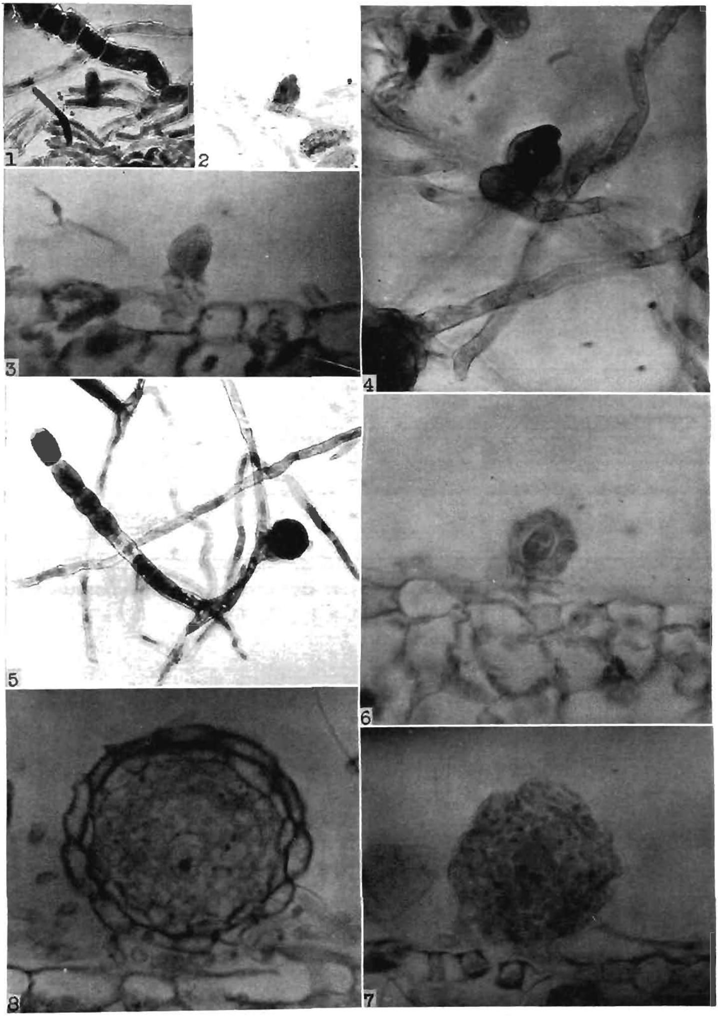
Fig. 13. *Phyllactinia Quercus* on *Castanea crenata*.
a. Perithecium, × 40. b. Appendage. c. Asci and ascospores.

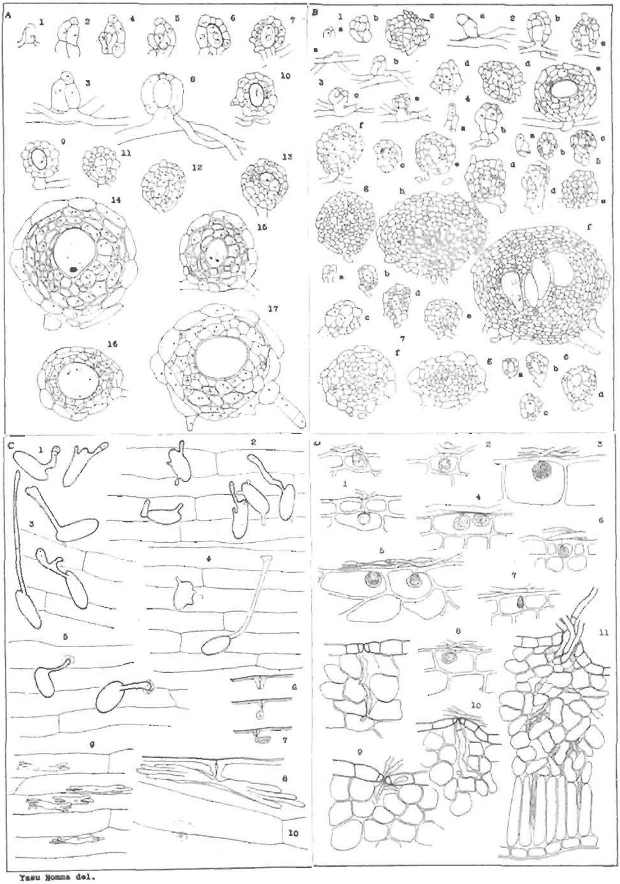
Fig. 14. *Phyllactinia imperialis* on *Paulownia tomentosa*.
a. Perithecium, × 40. b. Appendage. c. Asci. d. Conidia. e. Penicillate cell.

Fig. 15. *Leveillula taurica* on *Capsicum annuum*.
Conidia and conidiophores.

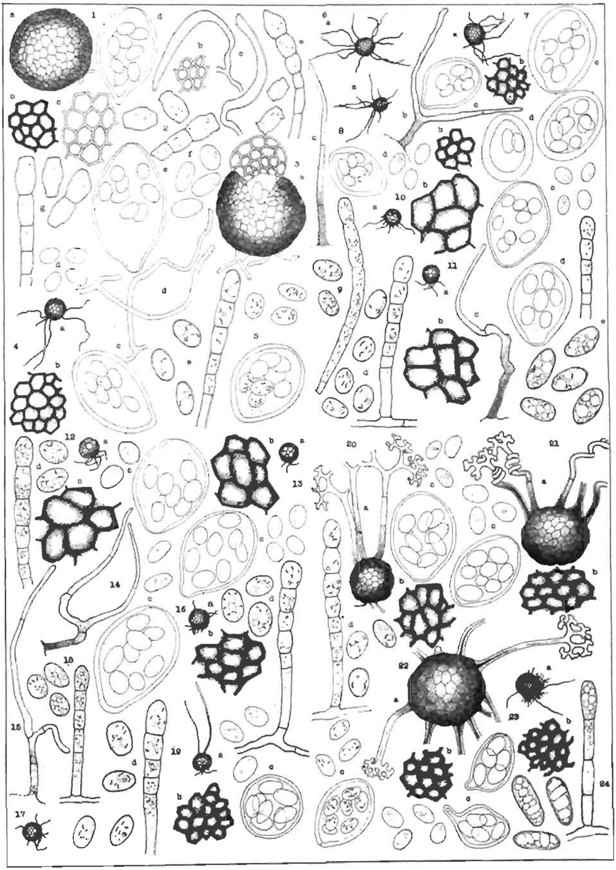


Yasu Homma del.


1
2
3
4
5
6
7
8

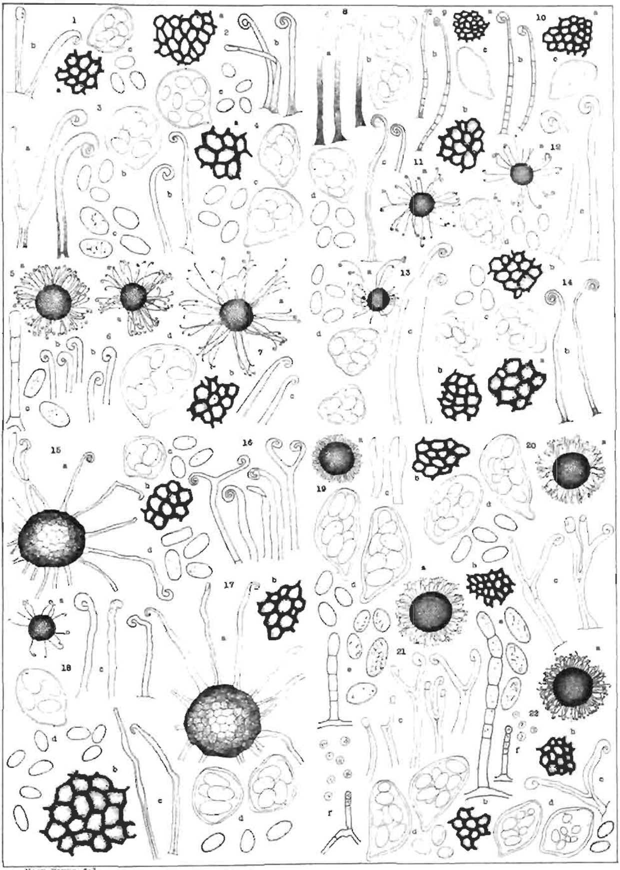


Yasu Homma del.

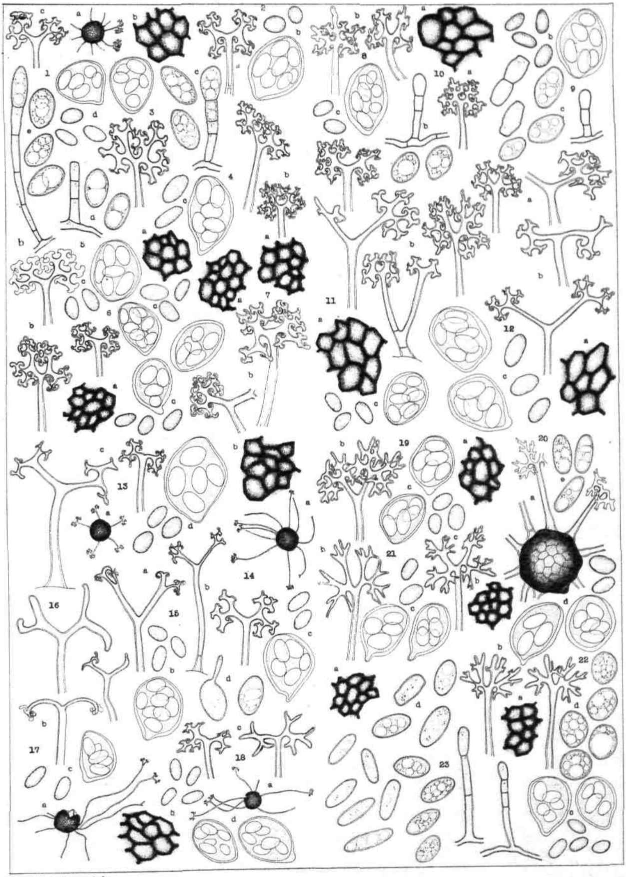


Yasu Homma del.

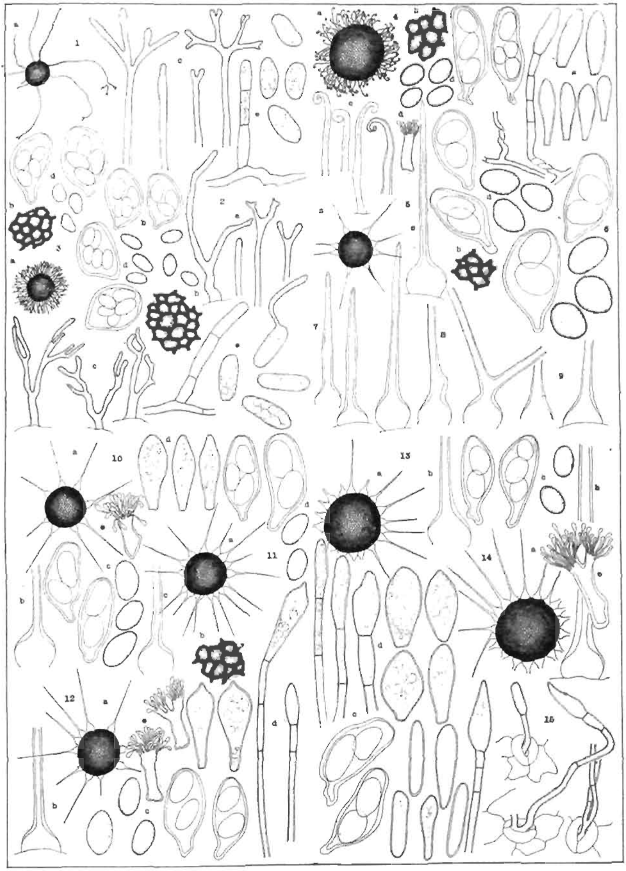
Yasu Homma del.



Yasu Homma del.



Yasu Homma del.



Yasu Homma del.